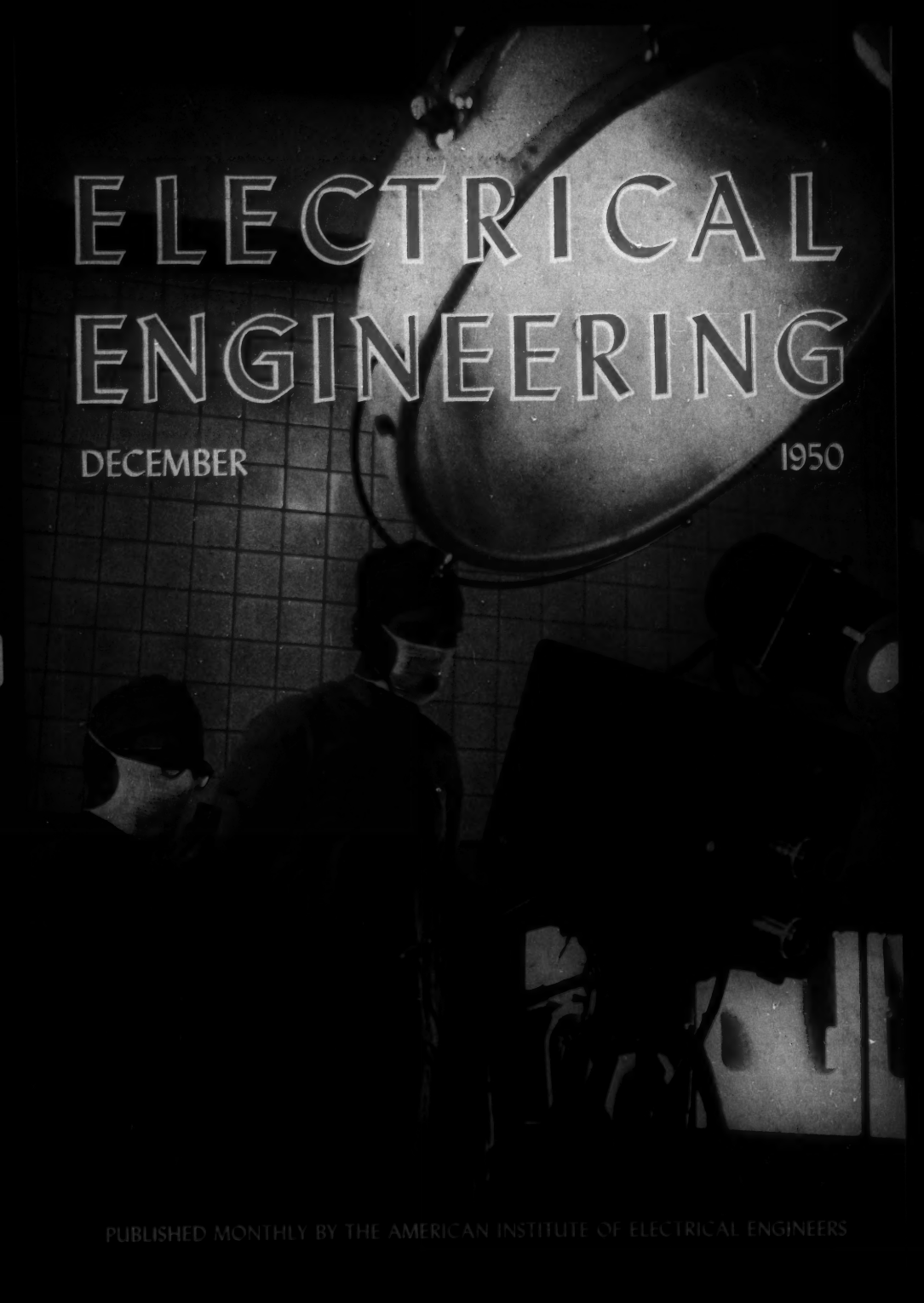
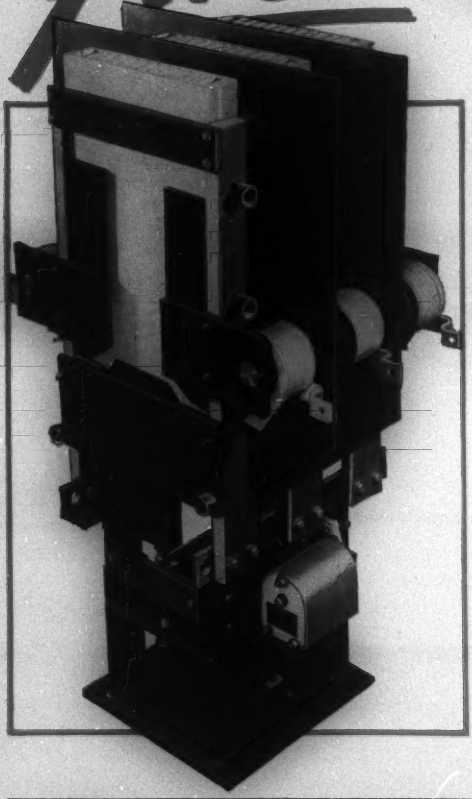


PUBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

First 50,000 KVA AIR CONTACTOR



ALLIS-CHALMERS TYPE 256 CONTACTOR
FOR 2300 TO 5000 VOLT MOTOR CONTROL

Maximum Rating of New Contactor	
400 Amperes	50,000 kva
60 kv impulse	19 kv @ 60 ~ for one min.
1500 hp @ 2500 V.	2500 hp @ 5000 V.
25,000 amperes through current for 30 ~.	

THE ALLIS-CHALMERS Type 256 Air Contactor series has been expanded to include a 400 ampere, 5000 volt contactor. It's the *first* air contactor with this high rating! The *first* air contactor to control 5000 volt motors to 2500 hp . . . 3000 hp at unity power factor!

This new contactor is designed to fit your control system into your distribution system in any one of these three ways:

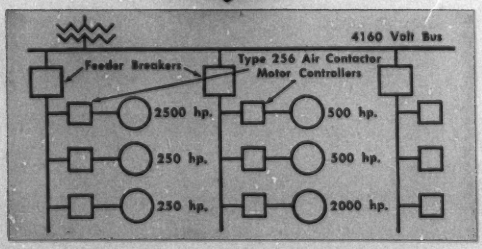
1. In conjunction with back-up breakers rated up to 25,000 amperes interrupting capacity; 150,000 kva at 4600 volts, 100,000 kva at 2300 volts.
2. With non-current limiting power fuses rated 250,000 kva and permitting instantaneous peaks to 54,000 amperes for one cycle.
3. Without back-up protection, on systems where faults cannot exceed 50,000 kva.

This 400 ampere air contactor will withstand short circuits up to 150,000 kva for 30 cycles. It provides a wide margin of safety when used with back-up circuit breakers with interrupting time of eight cycles.

Now, for the first time, this contactor provides both low initial cost and low maintenance cost for control of motors above 1000 hp at 2300 volts . . . above 1,300 amperes initial starting current. And it's recommended for continuous service on severe duty cycles!

For a contactor, a single starter, or an entire control group . . . to control squirrel-cage, wound rotor or synchronous motors . . . check with Allis-Chalmers. Call your nearby A-C representative or send for bulletins 14B6410 and 14B7303. A-3201

ALLIS-CHALMERS, 931A SO. 70 ST.
MILWAUKEE, WIS.



This new contactor, with its 25,000 ampere through current rating, permits cascading motor starter with a back-up breaker to protect a group of motors on systems up to 150,000 kva, 5000 volts.

ALLIS-CHALMERS

ELECTRICAL ENGINEERING

Registered United States Patent Office

DECEMBER

1950

This month's cover shows the Du Mont color television camera set up for action in the operating room at St. Clare's Hospital in New York (see page 1134 for story). Allen B. Du Mont Laboratories, Inc., photo

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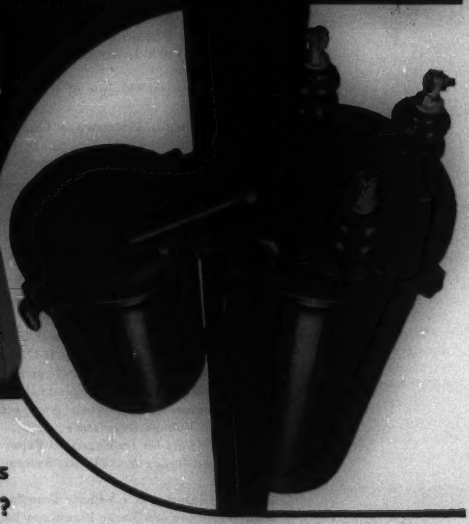

Why go on losing money on lines with so-called "adequate" voltage?

YOU MAY THINK 105v or 110v is "adequate." Lights work, motors run, stoves heat, and radios play. But they aren't operating at their rated voltage. Users are affected in many ways. Motor life is shortened . . . light bulb efficiency is low . . . heating is slow. Users are losing money whether they know it or not!

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You can use the band width advantage in three ways:

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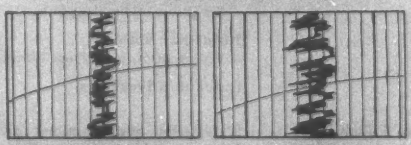

2 volt band **4 volt band**

The Allis-Chalmers pole type regulator is the only pole type step regulator that can hold a narrow 2 volt band. Use the band width advantage of this regulator to hold higher average voltage. Get quicker return on dollars invested in regulation.

ALLIS-CHALMERS

Originators of 5/8% Step Regulation

HIGHLIGHTS.....

Inflation, Dues, and Service. Some budgetary problems of the Institute are discussed by President LeClair this month, and in **Where Your Money Goes** W. J. Barrett, Chairman of the Finance Committee, explains some of the items of income and expenditure from the annual financial report (*pages 1049–51*).

Fall General Meeting Digests. Brief authors' digests of conference papers presented at the Fall General Meeting held in Oklahoma City, Okla., October 23–27, are included in this issue (*pages 1115–19*).

Carrier-Controlled Relay Servos. In this type of servo system a carrier voltage is used to control transmission characteristics of a relay. The uses of the carrier-controlled relay servo and an analysis of its characteristics are presented (*pages 1052–56*).

Obligations of the Engineer. The engineering profession is not understood by the general public. Dr. Kouwenhoven thinks this is because all those engaged in engineering have failed to educate the public to the services and responsibilities of the engineer (*page 1057*).

Field Testing a Microwave Channel. Transmission of three voice conversations, two types of protective relaying, two telemetered quantities, and supervisory control of eight points now is being transmitted by microwave channel to a reflector and from the reflector to the terminal equipment in an experimental installation of the Pennsylvania Electric Company between Seward and Johnstown, Pa. (*pages 1092–97*).

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Stereo-Television in Remote Control. The handling of radioactive materials has been made easier by the use of stereo-television. With this newly developed equipment, depth perspective is added to television pictures so that equipment can be handled safely and efficiently by master-slave controls (*pages 1058–62*).

Light Conditioning Homes. Many ideas for improving lighting in the home have been developed and are presented in the form of lighting recipes. These recipes specify the types and sizes of lights, proper fixtures, and the correct placement of the lamps for many seeing situations in the home (*pages 1066–69*).

Conduction Phenomena in Gases. The processes occuring in gases to cause them to change from insulators to conductors (that is, causing breakdown) are discussed. The subject is divided into three cases: (1) high-frequency fields; (2) d-c fields at low gas pressures; and (3) d-c fields at high gas pressures (*pages 1071–76*).

Electrical Work Injuries in California. The ratio of death-to-injuries in occupational accidents in California is 50 times higher in electrical accidents than in all other types of accidents involving work injuries. The Division of Industrial Safety of California is conducting a program of education and law enforcement to reduce such accidents (*pages 1076–77*).

Design of Electrical Education Buildings. Many ideas which should be incorporated in the design of a new electrical engineering building are discussed by J. D. Ryder, head of the Electrical Engineering Department, University of Illinois, and W. B. Boast, professor of electrical engineering, Iowa State College. They advocate that the building be planned to accommodate unanticipated future needs rather than be geared to the needs of the past (*pages 1081–86*).

The Graph-Scope. An instrument for plotting data electronically by means of a keyboard and presenting the curves on the screen of an oscilloscope has been developed recently. This versatile device allows the scales of the chart to be varied after the data has been inserted, so that it can easily be seen if the data fits any standard mathematical function (*pages 1097–1100*).

Unionmelt Voltage Controls. The varied applications to which Unionmelt welding has been put have required a number of types of welding voltage controls. The circuits and operation of three of these controls, electronic, series, and air, are described this month (*pages 1102–04*).

Loss and Recovery of Synchronism. The loss and recovery of parallel operation of a generator in a 132-kv power system, with a minimum of switchboard operating, is described in a way intended to be helpful to operating men. The cause of the loss of synchronism, the changes in the system, and the action needed to resynchronize the system are given (*pages 1105–07*).

Magnetic Amplifier Characteristics. A method, which has been checked experimentally, has been developed to calculate the steady-state characteristics of magnetic amplifiers in terms of data of design. This method entails applying Kirchoff's and Faraday's laws to the amplifier's electric circuits and using Ampere's laws in finding the relationship between currents and field intensities (*pages 1109–15*).

The article "Pulse Measuring of Deionization Time" by H. H. Wittenberg (*EE, Sep '50, pp 823–7*) was presented to the Graduate Division of Franklin and Marshall College, Lancaster, Pa., as a thesis, this being part of Mr. Wittenberg's work for the Master of Science degree awarded him in June 1949.

AIEE Proceedings

Order forms for current AIEE *Proceedings* have been published in *Electrical Engineering* as listed below. Each section of AIEE *Proceedings* contains the full, formal text of a technical program paper, including discussion, if any, as it will appear in the annual volume of AIEE *Transactions*.

AIEE *Proceedings* are an interim membership service, issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 567–8; Jan '47, pp 82–3*). They are available to AIEE Student members, Associates, Members, and Fellows only.

All technical papers issued as AIEE *Proceedings* will appear in *Electrical Engineering* in abbreviated form.

Location of Order Forms	Meetings Covered
Feb '50, p 46A	Winter General
Jul '50, p 30A	Winter General North Eastern District Great Lakes District Summer and Pacific General
Nov '50, p 43A	Middle Eastern District Fall General

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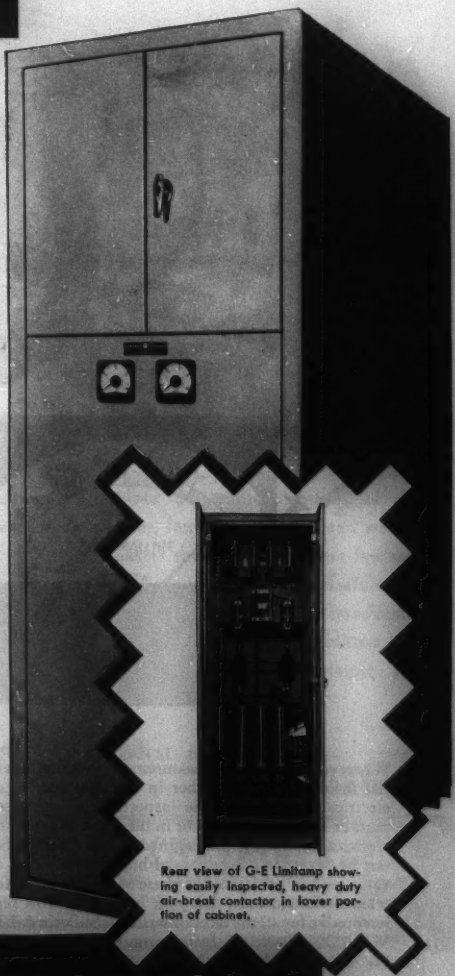

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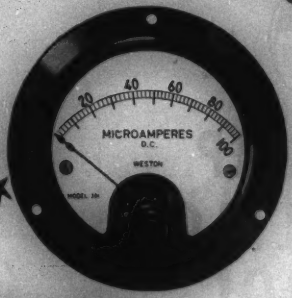

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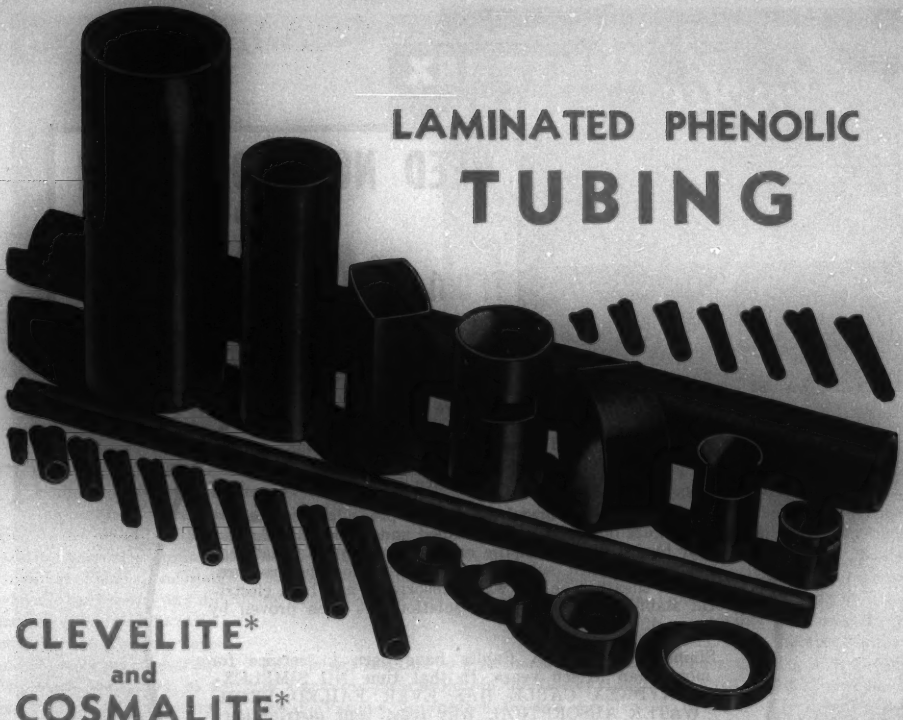

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Inflation, Dues, and Service

T. G. LeCLAIR
PRESIDENT AIEE

How is the Institute to give increased service to a growing membership in the face of rising costs? Various approaches to this problem are discussed by President LeClair.

THE INSTITUTE, like any other big family, has its budgetary problems, and these problems affect all of the Institute's operations and the services it is able to give to the rapidly increasing membership. During the past few years your Institute has moved gradually from a condition of being comfortably in the black to a situation where it has become very difficult to keep expenses within income. You will be interested in the Finance Committee's report on pages 1050–51, which shows that, as a result of careful administration, the 1949–50 operations came very close to the balance point. Figure 1 shows the distribution of income and expenditures for the fiscal year ending April 30, 1950, and Table I shows these items calculated on a per-member basis.

The rapid increase in membership means more pages of publications and to do our job properly means increased service to the members. How are we going to accomplish increased service in the face of rising costs for such items as paper, printing, salaries, and all the other expenses that go to make up our annual budget? Where do we go from here?

One approach to the problem is to cut expenses. One place to cut expenses would be to reduce the number of technical papers published. With the expanding nature of electrical engineering and with rapid advances in the art, engineers need this service and if the Institute does not give it, the result might be further fragmentation. Much of our money goes for publications. Could this expenditure be cut? *Electrical Engineering* and the *Transactions* are the only contact which some members have with the Institute and the only means by which new developments are made completely available. Also, reduction in the service rendered by the publications would reduce their reader interest and ultimately reduce the advertising revenue. The Section appropriations are the second largest item of expense. However, many of the Sections are now protesting that their appropriations are too small. It does not seem practical to reduce this item. Similar thoughts so far seem to apply to the other items of expense.

Another fundamental thought to be considered is the possibility of additional revenue from sources other than dues. The greatest present source of this revenue is advertising; however, advertising rates were raised in 1948 and at the present time are about as high as they could be without the risk of losing advertisers.

Various industries might be asked to contribute, or corporate membership might be established. Could we do this without destroying the independence of the individual member? A number of other sources of revenue have been considered, but so far none have appeared promising that would not sacrifice the high caliber and professional standing of the Institute.

Another possibility is to make a slight increase in the Institute dues to meet the present situation and await further developments. Some other engineering societies have faced the problem squarely by asking their membership for an increase in dues. The Institute has not had a change in the dues paid by its regular members since the year 1925. This is in spite of the steady increase in cost of all of the services which the Institute renders. The dues of enrolled students recently have been raised from $3.00 to $5.00, as the biggest increase in the cost of operation has been in the publication and the increment cost of the publication has risen to the point where this increase in dues was necessary to cover the large number of copies of *Electrical Engineering* distributed to students.

Raising the dues is not so simple as it would appear. The dues are now provided for in the Constitution and may

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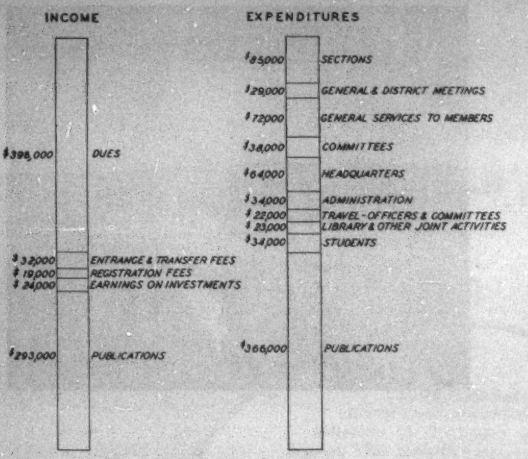

Figure 1. Distribution of income and expenditures for the fiscal year ending April 30, 1950

not be changed without a lapse of $1\frac{1}{2}$ to $2\frac{1}{2}$ years after a change is found necessary. If anything is to be done in the line of changing the Constitution, an amendment to the Constitution may be proposed by means of a petition signed by not less than 100 Fellows, Members, or Associates, and received by the Secretary not later than February 1; or by means of a resolution adopted by the Board of Directors not later than February 1. The ballot on such an amendment must be mailed not later than March 1. If favorably acted upon, the amendment becomes a part of the Constitution at the annual meeting in June, taking effect 30 days after this date. This means, of course, that any change in dues, even though needed right now, could not become effective until the May 1, 1952, dues statements are sent out.

If no change in the dues by Constitutional amendment could become effective now before May 1, 1952, and if the rising cost trend is expected to continue, it would be the better part of wisdom to ask for an amendment raising the average dues about five dollars, to avoid the necessity for frequent amendments.

If the rising cost trend should not continue, this increase would provide a nest egg for future expansion. It is difficult to predict the future and some members might object to higher dues unless they are immediately necessary.

As this story goes to press the most popular plan under discussion among the Board members is to propose an amendment to the Constitution transferring the amount of the annual dues to the By-laws where changes may be made on shorter notice by action of the Board of Directors. Some members might argue that their dues could be increased without the member having any choice in the matter. This lack of choice is more academic than real in any voluntary association, because the Board would not knowingly vote a dues increase which would bring a storm of protests or resignations. Offering a change in the Constitution to put the dues in the By-laws would give us another year to decide whether or not an increase is necessary without making the present commitment for such an increase when there is still a possibility that it might be avoided.

As stated previously, your officers are considering seriously the idea of moving the dues provisions from the Constitution to the By-laws. The Board of Directors, the Finance Committee, and the Committee on Planning and Co-ordination are all considering this question and will report to you later. The Board requested the preparation of this preliminary report as the problem warrants the consideration of all members. Any suggestions which you send to AIEE Headquarters, 33 West 39 Street, New York 18, N. Y., will be referred promptly to the appropriate committee.

Table I. AIEE Income and Expenditures for Fiscal Year Ending April 30, 1950

Item Number	Income	Per Member
1.	Dues, average	$12.13
2.	Publications	8.93
3.	Entrance and transfer fees, badges	0.97
4.	Meeting registration fees	0.59
5.	Earnings on investments	0.75
	Total	$23.37

Item Number	Expenditures	Per Member
6.	Publications	$11.17
7.	General and district meetings	0.89
8.	Sections	2.60
9.	Students	1.03*
10.	Technical committees	0.49
11.	General services to members and committees	2.19
12.	Membership committee	0.66
13.	Engineering Societies Library	0.53
14.	Other joint activities	0.18
15.	Traveling expenses—officers, representatives, and committees	0.66
16.	Administration	1.03
17.	Headquarters' expenses	1.96
	Total	$23.39
18.	Deficit	0.02

Notes: Number of members as of October 1, 1949, is 32,785.
Expenditure items include headquarters salaries allocated to these activities.
* Equals $2.55 per student member ($5.55 for student services less $3.00 student dues).

Where Your Money Goes

W. J. BARRETT
CHAIRMAN, FINANCE COMMITTEE

PERHAPS EVERY member of the Institute wonders occasionally about how the Institute's money—or rather, his money—is spent. A study of the financial statements in the Annual Reports of the Board of Directors, published each year in the August issue of *Electrical Engineering*, gives a detailed picture of the various items of income and expenses. Few members, however, have the time and inclination to analyze these reports carefully. The Finance Committee therefore has undertaken to analyze the report for the fiscal year which ended April 30, 1950, and to reduce it to a form easily digested. The result appears in Table I on page 1050.

In preparing this table the rather large number of separate items appearing in the Annual Report has been reduced by combining related operations into a reasonably small number of groups. Then everything has been divided by the number of members of the Institute as of October 1, 1949 (32,785 excluding students), so as to express the results on a per-member basis.

Explanatory notes for certain items follow.

Items 2 and 6. It will be noticed that the Institute derives a substantial income from its publications. This includes receipts for advertising in *Electrical Engineering*, nonmember subscriptions to *Electrical Engineering*, subscriptions to the *Transactions*, and the sale of miscellaneous publications such as preprints, Standards, and so forth. The publications expense includes the cost of *Electrical Engineering*, except for the extra copies printed for students, the *Proceedings* and *Transactions*, the *Year Book*, and the miscellaneous publications. Salaries of headquarters personnel employed in connection with publications are included and other incidental expenses, except rent which is a part of Item 17.

Items 4 and 7. Registration fees at General and District Meetings were introduced in 1948, and have helped substantially to reduce what would otherwise be a considerable drain on the Institute's treasury in this period of high costs.

Item 8. The expenditures for Sections include the allotments provided for in the By-laws which are turned over to the local Section officers, and also the travel allowances for the Section delegates to the Summer General Meeting. Stationery for the Sections is included.

Item 9. The incremental cost of furnishing *Electrical Engineering* to each student member is $4.10 per year. Student branch expenses and student prizes totaled $0.70 per student member. Traveling expenses paid in connection with Conferences on Student Activities and for student branch counselors to attend the Summer General Meeting account for another $0.75 per student. The gross expenditures per student therefore amounted to $5.55 during the fiscal year. Against this total the student dues of $3.00 have been credited. In accordance with action recently taken by the Board of Directors, the student dues have been increased to $5.00 which will more nearly balance the cost of services to the students.

Item 11. General services to members and committees cover a range of headquarters operations. A considerable portion of the headquarters staff is engaged in activities of such a varied and general nature that their salaries cannot be allocated to specific member services. They keep the books, carry on a voluminous correspondence with members, answer members' questions on a great variety of subjects, perform endless clerical services for committees, and so forth.

Item 13. The Engineering Societies Library located in the headquarters building in New York is administered by the United Engineering Trustees (UET). The UET is composed of representatives of AIEE and of the corresponding societies of civil, mechanical, and mining engineers. The library contains more than 150,000 volumes pertaining to engineering, physics, mathematics, and chemistry. In order to place the facilities of the library at the disposal of out-of-town members, a Library Service Bureau has been established, and a staff of expert searchers and translators is prepared to cover almost any engineering topic. Their services include abstracting, translating, making bibliographies, statistical searches and reports, searches for patent purposes, copying, and the like. Item 13 in the table represents the Institute's share of the cost of operating and maintaining the library.

Item 14. In furtherance of its object as stated in the Constitution, the Institute takes part in a number of activities sponsored jointly with other technical societies. Through participation in the UET, the Institute has a share in the administration of the Engineering Foundation. It is represented also on the Engineers' Council for Professional Development, the American Standards Association, Engineers Joint Council, the Canadian Council of Professional Engineers and Scientists, and a number of other joint bodies. Item 14 in the table represents our share of the cost of the activities of these organizations.

Item 17. This item includes the Institute's share of the cost of operating the headquarters building through UET—in other words, rent—as well as the rent for the editorial offices at 500 Fifth Avenue, and all those miscellaneous expenses that are incurred in the operation of an office, such as office equipment, printing and supplies, insurance, telephone and telegraph expenses, postage, and so forth.

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Carrier-Controlled Relay Servos

J. C. LOZIER
MEMBER AIEE

A CARRIER-CONTROLLED RELAY servo system is one in which a carrier voltage is supplied to the system, along with the signal, to control the transmission characteristics of the relay. The most familiar example of carrier-controlled operation is the self-oscillating relay servo, in which the carrier is supplied internally by the self-oscillations. However, the practice of supplying carriers from external generators for this purpose has grown rapidly over the last ten years.

An analysis has already been presented[1] to show that such systems are essentially linear in so far as their tracking performance is concerned, and that they may be treated as such. In this article the relationship between carrier-controlled relay servo systems and systems with proportional control is developed further in order to compare the capabilities and limitations on the tracking performance that can be obtained from each type. The results show that, by properly choosing the amplitude and the frequency of the carrier, the performance of a carrier-controlled relay servo can be made to match that of a similar system with proportional control, in all significant respects. The practical importance of this conclusion lies in the fact that a relay is the simplest and most efficient power amplifier known.

A study of servo systems shows that, when properly designed, the carrier-controlled relay servo will perform as well as a servo system with proportional control. In this article the problem of designing a carrier-controlled relay servo system for remotely tuning the variable capacitors of a transmitter is analyzed.

Some of the principles developed in the analysis are applied here to the problem of designing a carrier-controlled relay servo system for remotely tuning the variable capacitors in a radio transmitter.

THEORY

THE METHOD employed in analyzing these carrier-controlled relay servo systems is thought to be original. The mathematical aspects have already been described in chapter 9, reference 1, so this discussion will be restricted in so far as possible to the physical aspects of the problem.

The whole approach is based on an understanding of two transmission functions performed by the carrier:

1. The carrier serves to transform the relay into an essentially linear amplifier to the error signals. (Error signals are signals representing the difference between the desired and the actual position of the servo output.)
2. The carrier also serves to set the gain around the control loop for these error signals.

These two functions will be analyzed in turn.

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Linearization of Transmission through a Relay by Carrier Action. The first point to be demonstrated is to show how a carrier serves to linearize the transmission characteristics of a relay to a simultaneously applied signal.

A qualitative analysis of this action is shown in Figure 1. Curve *A* represents the carrier applied to the relay winding, and *B* represents the square-wave output of constant amplitude produced at the relay contacts. Curve *C* represents a signal, and *D* the sum of the carrier and signal at the input to the relay winding. Curve *E* shows the corresponding relay output.

When both the amplitude and the frequency of the signal are less than that of the carrier, the output of the relay will have a repetition rate set by the carrier frequency. The signal merely biases the relay so that it spends a proportionately longer part of each carrier period on one contact. It is apparent that the additional time involved will be proportional to the signal amplitude for signal amplitudes up to approximately one-half that of the carrier. Under these circumstances the output of the relay is a pulse-width modulated wave, and the variation in pulse width is proportional to the signal amplitude. When this pulse-width modulated wave is averaged over each cycle of the carrier, the envelope thus obtained is obviously an amplified version of the input signal.

This qualitative description of the transmission properties of a relay has been verified, and the necessary quantitative relationships have been determined by harmonic analysis.[1] The pertinent results are given by the two curves of Figure 2. These curves show how the amplitudes of both the carrier and signal components in the output of the relay vary as a function of the relative amplitude of these components at the input.

The signal curve of Figure 2 shows that the relay does continue to act as an amplifier to the signal for signal inputs above the −6-decibel level, referred to the carrier input. Although the signal input-output characteristic is not linear above this point, the maximum departure from linearity is only 2.5 decibels at an input signal level of approximately +1 decibel, referred to the carrier input. The signal amplification could be made precisely linear for signal input levels up to the peak carrier amplitude by using a triangular instead of a sinusoidal carrier, but this deviation from linearity is not important.

Dependence of Relay Servo Control Loop Gain on Carrier Amplitude. The second point to be demonstrated is to show

how a carrier can be used to regulate the control loop gain to error signals. In the usual case, where other elements in the system are essentially linear, the problem reduces to one of regulating the gain through the relay.

The output of the relay has a constant peak amplitude, and, in the absence of the signal, the output component at the carrier frequency is likewise constant for all usable values of the carrier input amplitude. Therefore, the gain through the relay to the carrier is inversely proportional to the carrier input amplitude.

The gain through the relay to a simultaneously applied signal is not so simple. It can be seen from Figure 1 that the variation in pulse width depends on the relative amplitude of the signal to that of the carrier at the input. Since the signal output is proportional to the variation in pulse width, it can be argued that the signal output is proportional to the ratio of the signal amplitude to the carrier amplitude at the input. In other words, the signal gain is inversely proportional to the input carrier amplitude, as is the carrier gain.

Figure 2 shows that, over the linear range of signal amplification, the ratio of the signal amplitude to the carrier amplitude is 6 decibels less at the output than it is at the input. Therefore, it follows that the gain for such simultaneously applied signals will be 6 decibels less than it is for the carrier. It is also shown in Figure 2 that the presence of the signal does not appreciably affect the amplitude of the carrier in the output when the signal input amplitude is relatively small.

Thus, for relatively small signal amplitudes, the gain through the relay to both the signal and the carrier is inversely proportional to the carrier input amplitude. Furthermore, the gain to the signal is 6 decibels less than it is to the carrier.

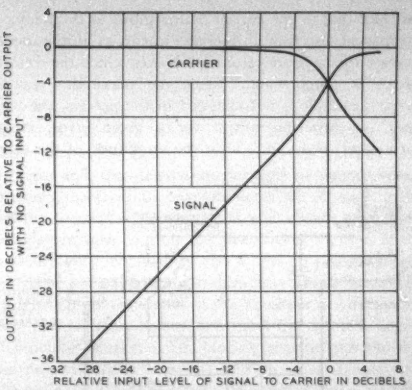


Figure 2. Input-output characteristics of a relay as an amplifier with simultaneously applied carrier and signal

It should be emphasized that this signal gain through the relay does not depend on the frequency of the signal, provided it is lower than the frequency of the carrier. Adjustment of the control-loop gain to the signal by changing the amplitude of the carrier, therefore, does not affect the relative gain and phase characteristics of the control loop as a function of frequency.

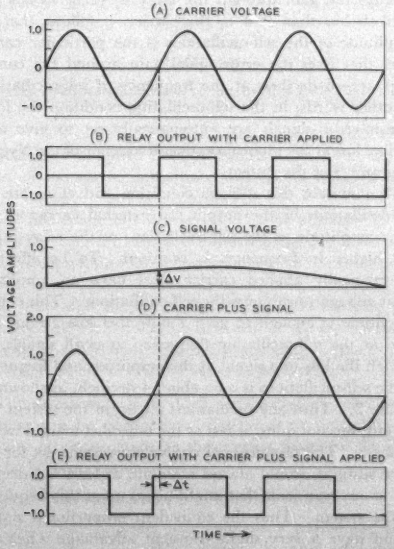


Figure 1. Operation of the relay when carrier and signal are applied

SERVO OPERATION UNDER CARRIER CONTROL

ONCE THESE essentially linear transmission properties of a relay under control of a carrier are known, the operation of such relay servo systems can be described qualitatively.

Take, for example, a positioning servo like that shown in Figure 3, where the error signal is proportional to the angular error. When the error signal exceeds the peak amplitude of the carrier, the relay is held on the proper contact to apply the full power available to drive the motor in a direction to reduce the error. When the error signal is less than the peak amplitude of the carrier, the relay will switch as the polarity of the combined error signal plus carrier reverses, and the power is alternately applied to drive the motor in opposite directions. For zero error the relay spends an equal portion of each cycle on each contact, so that the average power applied to the motor is zero. When the carrier frequency is high enough, this reversal will occur at such a high speed that the motor does not move. For intermediate values of the error signal, the relay is held a proportionately larger part of each cycle on one contact, and the net result is to apply a proportionate amount of power to drive the motor in a direction to reduce the error.

Thus the carrier transforms the system into one for which the restoring torque is essentially proportional to the amplitude of the error, for error signal amplitudes

less than that of the carrier at the input to the relay. It is apparent also that an increase in carrier amplitude will increase the range of error signals over which the restoring torque is proportional. Since the maximum restoring torque available is not changed in the process, the "stiffness," or restoring torque for a given error, is proportionately reduced. Thus the amplitude of the carrier

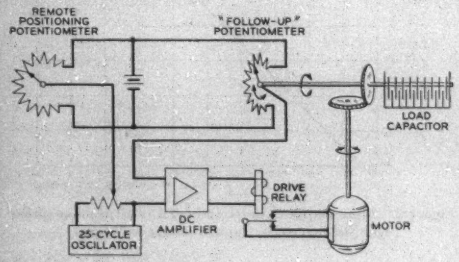


Figure 3. Block diagram of relay servo with external carrier

controls the stiffness, which is another way of showing that it controls the gain around the control loop by the error signals. In practice, factors that determine the range of proportional control are the stiffness desired and the maximum torque available, regardless of what type of control is used.

The purpose of the discussion so far is to make it clear that the only effects of the presence of the carrier on the control loop transmission to the signal are

1. To transform effectively the relay servo into a proportional one.
2. To provide a means of adjusting the control-loop gain by variation of the carrier amplitude.

This assumes, of course, that all the other elements in the system are linear and that the carrier frequency is higher than the signal frequencies.

The conclusion drawn from these results is that two servo systems, which differ only in the fact that one has a carrier-controlled relay drive and the other has any one of the more conventional forms of proportional drive, will have the same tracking performance when the control-loop gain is the same in each system.

The presence of the carrier in the carrier-controlled system will produce an oscillating motion in the output, which is superimposed on the average response, unless the frequency of the carrier is so high that the motor plus load cannot respond to it. When the carrier is supplied from an external oscillator there should be no difficulty in making the carrier frequency high enough to eliminate such oscillating motions.

CARRIER CONTROL VERSUS PROPORTIONAL CONTROL

It has been shown so far that a given servo system will have the same tracking performance, whether a carrier-controlled relay or a proportional drive is used, provided that the control-loop gain to the signal is the same in each system. Since both the static and dynamic characteristics of the tracking performance of a given system can be changed by varying this gain, the problem of comparing the capabilities and limitations of the two types of control reduces to one of comparing the range of usable gain adjustments in the two cases. Obviously, it is only at the upper limit of gain adjustment where significant differences will occur.

A servo system with either type of control will oscillate when the stiffness is great enough. Relay servo systems are often used when oscillating, and their tracking performance is remarkably good, if the oscillating motion in the output can be tolerated.

The frequency of self-oscillation will be the frequency for which the phase lag around the control loop is 360 degrees, and the amplitude of the oscillations will stabilize at the precise level to give 0 decibels gain around the loop to these oscillations.

At the frequency of self-oscillation the fedback voltage from the servo output is in phase with, and therefore adds to, the error signals resulting from an applied signal at this frequency. Therefore, the self-oscillating frequency is above the frequency range of applied signals for which the particular servo system can successfully operate, and the self-oscillating frequency is automatically high enough to fulfill the frequency requirement on the carrier for satisfactory error signal amplification of the relay. As far as the control-loop transmission-to-error signals are concerned, no improvement could be made by introducing a higher frequency carrier of the same amplitude from an external generator.

Since the gain through the relay to small signals is 6 decibels less than it is to the carrier, it follows that the amplitude of the self-oscillations is the particular carrier level that fixes the error signal gain around the control loop at -6 decibels at the frequency of self-oscillations. In other words, in the self-oscillating condition the loop-gain-to-error signals are automatically set to give a 6-decibel loss at the phase cross over frequency of the Nyquist diagram[1-4] of the system.

To maintain this stiffness condition and eliminate the self-oscillations in the output, an external carrier of the same amplitude as the self-oscillations at the relay input, but higher in frequency, is required. To be effective, an externally applied carrier must have an amplitude great enough to suppress the self-oscillations. This carrier amplitude is enough to give a 6-decibel loss around the loop at the self-oscillating frequency to small signals, although the loss to a signal at the amplitude and frequency of the self-oscillations is only about 4 decibels, as shown on Figure 2. Thus any oscillations set up in the system will die out, but not quite as fast as the 6-decibel margin would indicate. The proportional equivalent system, set for the same stiffness, would always maintain at least a 6-decibel loss to any transients that might be set up at this frequency in the system. Thus the equivalent proportional system would have a very slight transient advantage when the loop gain is set to give a 6-decibel loss at the phase cross over frequency.

At greater loop gains, this difference in effective transient damping between the two systems would increase. On the other hand, when the stiffness is reduced 2 decibels, so that there is an 8-decibel loss around the control loop at the phase cross over frequency for small signals, the loss to a transient at the amplitude and frequency of the self-oscillations would be approximately 7.5 decibels. Thus the difference between the carrier-controlled system and its proportional equivalent rapidly disappears as the stiffness is reduced.

It is questionable whether or not stiffnesses greater than that represented by a 6-decibel loss around the control loop at the phase cross over frequency can be profitably used in any practical application. It can be shown that the dynamic tracking accuracy (accuracy in following rapidly varying signals) deteriorates very fast, due to the highly underdamped nature of the transient response, when the stiffness is increased beyond this level. On the other hand, the static tracking accuracy should continue to increase proportionately with the stiffness. Certainly no more than a 2- or 3-decibel increase would be possible in any case, before the system would be too sensitive to variations in loop gain with variation in circuit components, line-voltage variations, and so forth, to be practical.

In any event this difference in transient damping, which occurs because of the increase in the ratio of loop gain to signals when their amplitudes approach that of the carrier, could be eliminated if it were important in any practical carrier-controlled servo system, by resorting to a sawtooth rather than a sinusoidal carrier.

Since there is little use in a practical system for a stiffness greater than that for which the gain around the control loop is more than -6 decibels at the frequency of phase crossover, this difference in transient performance at higher stiffnesses is not important.

SUMMARY

In the foregoing analysis it has been shown that:

1. In a carrier-controlled relay servo system, where the carrier is supplied from an external generator, adjustment of the carrier amplitude will give a linear control of the effective stiffness of the system.
2. The range of stiffness that can be obtained in this way is the same for all practical purposes as that obtainable in a system with a more conventional form of proportional drive.
3. For each setting of the stiffness, the tracking performance for a given servo system will be the same whether the carrier-controlled relay or a proportional drive is used, provided the stiffness is the same in both cases.

The conclusion is that carrier-controlled relay servo systems can be designed to give the same flexibility and quality of performance as those using more conventional forms of proportional drive.

APPLICATION TO TUNING SERVO

The example under discussion is a positioning servo designed for remotely tuning a variable capacitor in a commercial design of radio transmitter. The transmitter has ten such variable capacitors, all servo controlled.

A block schematic of a single servo unit is shown in Figure 3. The tuning can be performed from the front panel where a remote positioning potentiometer is used to generate a signal voltage proportional to its angular position. A follow-up potentiometer, attached to the capacitor being driven, yields a voltage proportional to the angular position of the capacitor. These two potentiometers form a bridge, and the unbalanced voltage or signal, which represents the error in positioning, is fed through a d-c amplifier to control the operation and release of a relay. The relay in turn controls the direction of rotation of the motor driving the capacitor and follow-up potentiometer. There is no neutral position in this relay, and the sensitivity of the bridge and the gain of the amplifier is sufficient to insure positive relay action on a small fraction of a degree difference of rotation. The block schematic also shows a 25-cycle oscillator arranged to feed an adjustable amount of 25-cycle voltage or carrier to the input of the d-c amplifier, along with the voltage unbalance of the bridge, which represents the positional error.

The governing requirement on the motor speed for this use is that the system be able to make a full revolution in 15 seconds. The maximum torque required to turn the capacitors was set at 3.5 inch-pounds. The motor selected is a 2-pole shaded-pole reversible a-c motor with a nominal speed, after a 450-to-1 gear reduction, of 5.5 rpm, and a stall torque of 10 inch-pounds.

The servo was set up with this motor as shown in Figure 3. The d-c amplifier gain is sufficient to operate the relay on 0.01 volt at the amplifier input. The voltage across the follow-up and remote positioning potentiometers is large enough to shift the voltage on the grid of the d-c amplifier by 0.7 volt for each degree of error in the capacitor position.

With this motor in the system and with the 25-cycle carrier shut-off, the self-oscillating frequency is approximately 3.5 cycles per second, and the amplitude at the capacitor shaft is approximately ± 0.7 degree when the load is approximately 3 inch-pounds.

The dynamic requirements on the tracking capabilities of these servos are fairly lenient since the servos need only follow well enough to permit satisfactory hand tuning of the transmitter from the remote positioning potentiometers on the front panel.

The primary requirement here is on reset accuracy. The transmitter in this case may be assigned a group of frequencies, and each servo has a separate remote positioning potentiometer on the front panel for each frequency. A selector switch is arranged so that at each step it connects a particular set of these potentiometers to the servos. Thus once a set of these potentiometers has been adjusted to tune the transmitter to a given frequency properly, they are locked in position. Then the transmitter can be retuned to that particular frequency merely by setting the selector switch to the correct step. When the transmitter is returned by this selector switch action, it is estimated that a reset of the corresponding capacitors to within ± 1.0 degree of their original positions would assure retuning of the transmitter to within commercial limits.

When the 25-cycle-per-second carrier is added to stabilize

and linearize the system, excellent reset accuracy is obtained when the carrier is approximately 4 decibels above the amplitude the self-oscillations would have if the external carrier were not present. A further increase of 6 decibels in this carrier amplitude introduces about 0.1 degree of reset error. Of course, variations in power, tubes, and so forth, will introduce additional sources of error, so that the over-all performance will not be this good. The dynamic performance of the system is satisfactory for hand tuning for an even wider range of 25-cycle carrier amplitudes. Therefore, the ten servos on each transmitter are supplied from the same oscillator with just one amplitude control.

One model of this transmitter was tuned to four different frequencies with four sets of remote positioning potentiometers, and a cover was placed over these potentiometers so that their adjustments would not be disturbed. Then daily checks were made on the over-all tuning performance and on the reset accuracy of each of the ten servos for a 4-month period. At the end of the period the transmitter tuning at each frequency was still satisfactory for commercial use. The first and last readings on the 40 servo positions involved (ten servos and four positions each) were lumped together for statistical purposes and treated as though all readings were made on one servo position. It was found that:

1. The change in position on the average was less than 0.1 degree.
2. The standard deviation of the individual errors was 0.42 degree.

In taking these data the individual readings could only be estimated to 0.35 degree.

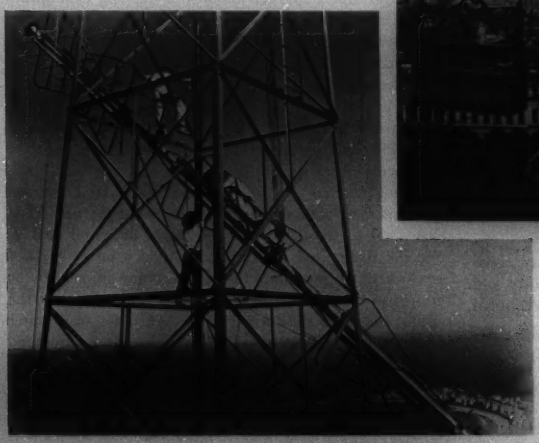
The over-all accuracy in retuning the transmitter to a particular frequency has proved to be excellent. The system reflects the practical advantages of the carrier-controlled technique. The individual servos have the simplicity and the efficiency of a relay servo and the accuracy and stability of a conventional linear servo.

REFERENCES

1. Fundamental Theory of Servomechanisms (book), **L. A. MacColl.** D. Van Nostrand Company, New York, N. Y., 1945.
2. The Servo Problem as a Transmission Problem, **E. B. Ferrell.** *Proceedings*, Institute of Radio Engineers (New York, N. Y.), volume 33, October 1945, pages 763–7.
3. Linear Servo Theory, **Robert E. Graham.** *Bell System Technical Journal* (New York, N. Y.), volume 25, number 4, October 1946, pages 616–51.
4. Principles of Servomechanisms (book), **G. S. Brown, D. P. Campbell.** John Wiley and Sons, Inc., New York, N. Y., 1948.

Television Station Installed Atop Rio's Sugar Loaf Mountain

One of the 115 cases of television transmitting equipment is being carried via cable car to the summit of Sugar Loaf Mountain where it will be installed 1,300 feet over Rio de Janeiro. Because Sugar Loaf Mountain is inaccessible otherwise, all the transmitting equipment, including the 150-foot antenna, had to be carried to the summit by cable car, mule-back, and by hand. The job was time-consuming because the engineers could use the cable car, which is popular with tourists, only between 4 and 8 a.m.



"Batwings" on Rio's new television antenna are being removed temporarily by workmen to facilitate raising the topmost section. Engineers of the International General Electric Company are installing the transmitting equipment atop Sugar Loaf Mountain high over nearby Copacabana Beach, lower right. Brazil, first South American country to have regularly scheduled commercial programs, will have several thousand television receivers in operation by the end of the year.

Obligations of the Engineer

W. B. KOUWENHOVEN
FELLOW AIEE

The engineering profession is not understood by the general public, Dean Kouwenhoven feels, because all those engaged in it have failed to meet their full obligations.

THE ENGINEER, using the discoveries of pure science, has during the past 50 years revolutionized the home, commerce, communications, manufacturing, farming, and, unfortunately, war also. The engineer is a "doer." That is, he likes to do things to make the world a better place to live in; to lighten our daily tasks. Why is it then that a profession which has created this new world and given us leisure is so little understood by the public in general? Because all of us, the student, the engineering school, industry, the technical society, and the engineer himself, have failed to meet our full obligations. We have made a dismal failure in dealing with things of the spirit.

The young man who chooses to study engineering should be able to defend his selection of a profession. He should realize that engineers, due to the nature of their work, tend to become impersonal and unemotional. The student should take an active part in college life to help counteract this tendency. He should endeavor to become a competent, well-rounded man, and to acquire technical knowledge and an understanding of his fellows. His guiding star should be service rather than personal aggrandizement.

Our engineering schools now recognize that a purely technical training is not enough and that some time must be devoted to cultural subjects. They realize that it is their obligation to train the young engineer not only in the rigid discipline of mathematics and the fundamentals of science, but that they must also teach him history, and awaken his interest in human beings, their motives, their superstitions, their physical limitations, their strengths, their weaknesses. This is a difficult assignment because the majority of engineering students tolerate cultural courses because they cannot get their degrees without them. Our schools must see to it that their engineering staffs are made up of broad-minded men with wide interests, who are also technically competent. Then they must search for teachers of cultural subjects who understand the philosophy of the engineering student "that knowledge, to be good, must be useful."

In addition the engineering school should be careful not to stifle the inquisitiveness, imagination, and ingenuity of its students; rather it should attempt to develop these traits. Above all, the teacher should make the student realize that his life is to be one of service and that the compass of existence holds far more than the textbook.

Industry's first obligation is to carry on where the college leaves off, taking into consideration that it is only possible to do just so much in four years of college. The first years of the engineering graduate's industrial experience constitute an internship. The proper carrying out of this internship calls for leadership of a high order on the part of industry. Perhaps it would be well if industry and the engineering school formed a partnership.

The young engineer must be made to realize that engineering education is a continuing process. Especially well-qualified men should be encouraged and be given the opportunity to take advanced training. Industry should, however, make it clear that engineering ability and technical skill alone will not get a man to the top. Understanding of human relationships and knowledge of the social graces are also essential.

Industry has another obligation, namely, to take its proper part in the life of the community. It should not only urge its young engineers to be active in technical and community affairs, but it should expect and encourage its older engineers with established reputations to serve on committees, boards, and drives.

Technical societies must help meet the challenge that is threatening their existence. One of their obligations is to educate the public as to the duties, responsibilities, and services performed by the engineer. They should become more public minded and devote at least a portion of their energies to public affairs and toward a sympathetic approach to the human problems of their membership and the public. They should ask themselves what they are doing about our profession, are they selling it to the public, are they building up good will, are they making engineering attractive to qualified young men?

Would it be heresy for our great founder engineering societies to maintain a radio or television program? Why should these creations of the engineer serve mainly as a means for the politician to sway public opinion?

Since the last crisis that threatened our civilization the engineers and the scientist have gone right ahead creating new devices without regard to their effects on our world. Many believe that modern technology is firmly established and will continue. This feeling of security is not justified. We may have created a Frankenstein.

The engineer is essentially a problem solver. He starts with a foundation of facts on which he builds logically and honestly with an eye to the over-all economy and utility. He knows from experience when slide rule results are close enough and when greater accuracy is required. He works best when he has a problem to solve and a limited time in which to solve it. He has a problem now that must be solved if this way of life is to continue.

Essentially full text of an address presented at the AIEE Middle Eastern District Meeting, Baltimore, Md., October 3-5, 1950.

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Stereo-Television in Remote Control

H. R. JOHNSTON C. A. HERMANSON H. L. HULL

THE STUDY of the possibilities of using 3-dimensional television in conjunction with remotely controlled electric manipulators is part of a long-range development program being undertaken by the Remote Control Engineering Division of the Argonne National Laboratory.

Manipulation of objects in 3-dimensional space requires that depth perception be incorporated into any scheme used to view and control the means of manipulation. It is not sufficient to use ordinary 2-dimensional television for this purpose since the ability to judge depth is almost entirely lacking.

The study which was undertaken had as its object the development of a workable system of 3-dimensional television which could point the way to a practical method of viewing and operating remotely controlled manipulators.

THEORY AND HISTORY OF STEREOSCOPY

HUMAN BEINGS are enabled to judge depth in 3-dimensional space chiefly because they have two eyes, each of which sees a slightly different view of the objects in the space before them. Other factors which contribute to depth perception are accommodation or focusing of the eyes, perspective, variations of light, parallactic displacement, and experience.

Stereoscopy may be defined as the art and science of producing depth-perception effects with the aid of special apparatus for viewing a pair of 2-dimensional pictures, each of which is taken from a slightly different horizontal position in space. Although the viewing of stereoscopic pairs of 2-dimensional pictures gives a greatly improved depth perception over the ordinary single 2-dimensional view, it can never give a perfect illusion of reality since several elements inherent in natural vision are missing. For example, no change of accommodation or focusing of the eyes is necessary when the attention is directed from a near to a more distant object in the scene.

An experimental 3-dimensional television system has been developed for the purpose of investigating its use as a viewing system for remote manipulation in atomic energy research. Standard television equipment has been modified by the use of stereoscopic principles to evolve this useful equipment.

The fundamental principle to be observed in stereoscopic viewing is that each 2-dimensional picture should be seen only with the eye corresponding to the lens of the camera with which the picture was taken. Many methods of accomplishing this requirement have been used. In the old-fashioned stereoscope, the two pictures are separated by a physical partition placed between the eye pieces and the stereoscopic pair of pictures.

In projection stereoscopy, three methods have been used. The first method involves the use of two superimposed projected images in two complementary colors, red and green. Spectators are provided with red and green spectacles so that each eye sees only its correct picture.

A second method uses polarized light to separate the two images on the screen. In this method, the stereoscopic pair of pictures are projected superimposed on the screen as before, but the light from each image is polarized by polarizing filters which have their axes of polarization at right angles to each other. The spectators are provided with spectacles holding a pair of crossed polaroid filters so that each eye sees only its proper image.

A third method, which has been called the eclipse method, consists in the projection in rapid succession of two stereoscopic pictures on a screen by the use of a rotating shutter. Spectators are equipped with a rotating shutter which is held before the eyes and this shutter is synchronized with the shutter on the twin projector.

STEREOSCOPIC TELEVISION

A STANDARD DuMont television pickup chain was employed in the development of stereo-television. This equipment was modified so that two different lines of approach to the problem could be explored. The first approach is the time-division method and the second, the simultaneous method.

The time-division method used a mechanical rotating shutter and an optical system consisting of full- and half-silvered mirrors. The left- and right-eye images were sequentially projected onto the photocathode of the television camera tube. This system was abandoned because of image carry-over and flicker. The simultaneous method was the one finally adopted. In this method the stereoscopic pair of images are transmitted simultaneously instead of sequentially in time. The two images are placed side by side in the same space normally occupied by a single image in standard 2-dimensional television picture transmission.

Two variations of the simultaneous method have been tried. The first variation used a single lens and a beam-splitter attachment as shown in Figure 1. This scheme was dropped in favor of a 2-lens arrangement.

The twin-lens system was found to be superior to the

Full text of a paper presented at the National Electronics Conference, Chicago, Ill. September 25–27, 1950.

The work reported in this article was carried out by H. R. Johnston and C. A. Hermanson of the Remote Control Engineering Division of Argonne National Laboratory, Chicago, Ill., under the direction of H. L. Hull. H. R. Johnston, who was on leave from Northwestern University while doing this work, is now a graduate student at the University of California, Berkeley, Calif.

beam splitter because the optical quality of the individual images was greatly improved and the image overlap in the center was reduced. Figure 2 shows a diagrammatic sketch and Figure 3 is an illustration of the first arrangement of the twin lenses and mirrors that were used for this method of stereo-television.

In the Model 1 version of the twin-lens system, two 105-millimeter lenses were used. The distance between the centers of the two lenses was three inches, which is similar to the normal interocular distance in human beings. The lenses were arranged so that they would be slightly rotated about a vertical axis and thus be converged on a near-by object. This action is similar to the convergence of the human eyes.

At the receiving end of the stereo-television system the two images appear side by side on the face of a standard kinescope or television picture tube. The right-eye view is on the left side and the left-eye view on the right side as the observer views the face of the receiving tube (see Figure 4). This transposition of images is due to the geometry of the optics used (see Figure 2).

Two polarizing filters whose axes of polarization are at right angles to each other are placed immediately in front of the images on the cathode-ray tube. An observer wears a pair of polarizing spectacles so oriented that the right eye is permitted to see only the right-eye image and the left eye sees only the left-eye image. In addition, a pair of 10-degree glass prisms are placed in front of the eyes to enable the observer to fuse the two pictures into a single 3-dimensional image of the objects in front of the camera (see Figure 4). Figure 5 shows an observer viewing the receiving tube while wearing the polaroid spectacles and prisms.

In the Model 1 twin-lens arrangement the horizontal distance between lenses was strictly limited and fixed. In the Model 2 twin-lens arrangement the effective distance between view points is variable from five to seven inches. The mirrors were made adjustable for both distance between viewpoint and for convergence of the images. The lenses used were of 90-millimeter focal length (see Figures 6 and 7).

In both twin-lens assemblies, it was necessary to provide a light barrier between the images as shown in Figures 2 and 6. This was done to prevent overlap of images in the center of the camera tube. It was important to make this barrier telescope so that focusing could be done in the normal manner by mechanical movement of the television camera tube, relative to the stationary lens.

A second method used to view the 3-dimensional television pictures makes use of two television picture tubes. These tubes are arranged at right angles to each other and a semitransparent mirror is placed so that it is at 45 degrees with both tubes (see Figure 8). Crossed polarizing filters are placed in front of each picture tube, and the observer wears crossed polarizing spectacles. Both images of the stereo pair appear on the tubes, but by means of positioning controls and masks, the right-eye picture is placed in the center of one tube and the left-eye picture in the center of the other tube. The observer is enabled to see the 3-dimensional image by observing one image by transmission

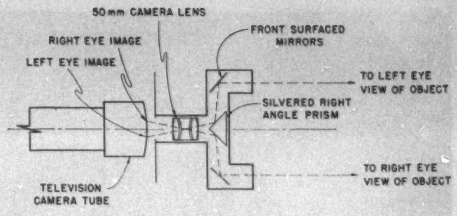
50 mm CAMERA LENS
RIGHT EYE IMAGE
LEFT EYE IMAGE
FRONT SURFACED MIRRORS
TO LEFT EYE VIEW OF OBJECT
SILVERED RIGHT ANGLE PRISM
TO RIGHT EYE VIEW OF OBJECT
TELEVISION CAMERA TUBE

Figure 1. Diagram of the simultaneous method using a single-lens beam splitter

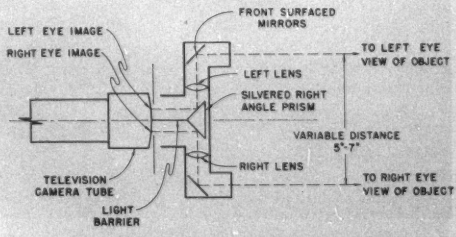

Figure 2. Diagram of Model 1 twin-lens arrangement for simultaneous viewing

Figure 3. Model 1 twin-lens stereo unit

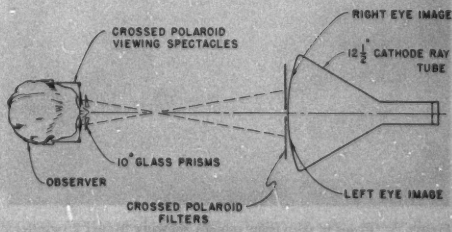

Figure 4. Diagram of single-tube stereo-television viewer

Figure 5. The observer wears polaroid spectacles and prisms while using the single-tube stereo-television viewer

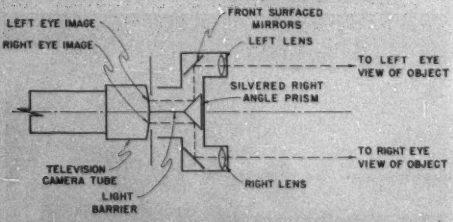

Figure 6. Diagram of Model 2 twin-lens arrangement

Figure 7. Front of television camera showing Model 2 twin-lens assembly in use

through the semitransparent mirror and the second image by reflection.

VIEWING METHODS

TWO METHODS of viewing the 3-dimensional images have been described. These might be called the single-picture-tube viewer and the twin-picture-tube viewer. Both methods require the observer to wear crossed polarizing spectacles.

Method 1 or the single-tube viewer requires, in addition, a pair of glass prisms to be attached to the polarizing spectacles. These glass prisms aid the eyes to fuse the side-by-side images into one stereo-image. The prism angle should be of such a value that the observer can converge and focus his eyes naturally on the face of the picture tube. This condition is necessary for minimum eye strain in observers.

The use of glass prisms by the observer results in a number of difficulties. The principle difficulty is that the attention must always be directed to the television screen since every other object in view appears double. Severe eye strain and mental discomfort result when the attention is directed to the hands in an attempt to operate switches or other devices.

A second difficulty associated with the 1-tube viewing method lies in the necessity for precise orientation of the head of the observer in relation to the viewing tube. It has been found that a rotation of only 5 degrees of the observer's head about a horizontal axis perpendicular to the center of the viewing tube is sufficient to cause loss of the stereo-image. Since a relatively fixed relationship between the angle of the correcting prisms and the distance to the viewing tube must be maintained, it is only with considerable difficulty that two or more observers may view the single tube stereo-image at the same time.

Viewing Method 2 or the twin-tube stereo-viewer is by far the more desirable of the two methods. In this method the observer is required to use only a pair of polarizing spectacles without prisms. The superposition of the two images is accomplished by the use of the half-silvered mirror and positioning controls of the television receiving units.

Since no prisms are used, the observer may look from the viewing screen to other objects in the room such as controls and switches without danger of severe eye strain as in the first method. This method also permits considerable translation and rotation of the head of the observer before the stereo-illusion is lost. Several persons may easily observe the stereo-image at the same time.

OPERATING NOTES

CONSIDERABLE thought was given to the supposed necessity for a high degree of linearity in the sweep circuits of the receiving and transmitting units before the tests were

completed. It was found, however, that a considerable amount of nonlinearity in the sweep circuits could be tolerated without serious impairment of the stereo-illusion.

Slight differences in the sizes of the two images could be reconciled by the brain with some fatigue involved.

It was found, however, that appreciable vertical displacement of the images could not be tolerated. It should be pointed out that, while the human eyes and brain have a high degree of tolerance, every effort should be made to obtain the best possible linearity and definition to avoid operating fatigue.

In the twin viewer, the observer should have the illusion of looking through a window on the face of the viewing tubes. This illusion is obtained only with careful adjustment of the two stereo-images. Assuming that the two pictures are linear and of the same size, the first adjustment should be to line up the images in a vertical direction. In a horizontal direction, the two images of the object which is nearest the television camera are superimposed. This procedure locates this nearest object in the plane of the viewing screen and all other objects appear to be behind the window formed by the surface of the picture tube.

A pair of images, as seen on the single tube viewer, is shown in Figure 9.

Careful masking of the sides and top of the two images was also found to be necessary to preserve the window illusion. After the images are adjusted the masks should be carefully aligned so as to appear coincident.

In stereo-television it is desirable to obtain images which have sufficient size, contrast, and brilliance. The use of polarizing filters and half-silvered mirrors in the stereo-receiver necessitates a greatly increased brilliance in the received image due to the large light losses in these elements. Approximately 60 per cent of the light of the image is lost in the first polarizing filters; 60 per cent of the remaining light then is lost in the half-silvered mirror, and another 10 per cent of the light is lost in the polarizing spectacles. This results in a loss of approximately 85 per cent of the total light available.

In this investigation, $12\frac{1}{2}$-inch-diameter television tubes with an aluminum-backed screen were used. In order to obtain increased brilliance a somewhat higher than normal accelerating voltage (12,000 volts) was applied to the picture tube. In the twin-tube viewer it is essential that a well-regulated high-voltage supply be used so that the size of the image does not change when brightness and contrast controls are adjusted.

It is essential that the camera lenses be adjusted for the proper convergence angle for each distance from the object to the camera tube. It was found that the convergence could best be adjusted by observa-

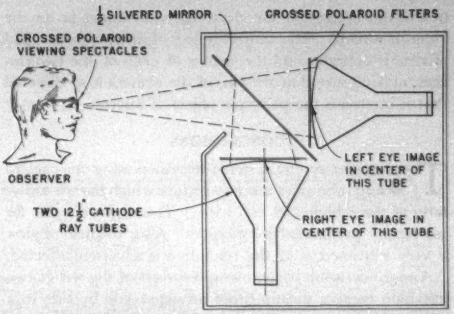
½ SILVERED MIRROR
CROSSED POLAROID FILTERS
CROSSED POLAROID VIEWING SPECTACLES
OBSERVER
LEFT EYE IMAGE IN CENTER OF THIS TUBE
TWO 12½" CATHODE RAY TUBES
RIGHT EYE IMAGE IN CENTER OF THIS TUBE

Figure 8. Diagram of the twin-tube stereo-television viewer showing the tubes at right angles to each other. One image is seen by reflection and one by transmission through the semi-transparent mirror

Figure 9. Pair of stereo-television images as seen on the single-tube viewer

Figure 10. Stereo-television camera and the slave hands of the master-slave manipulator in operation

tion of the images on the electronic view-finder or on the monitor screen. The central object of interest in the field of view is brought into the center of each of the two images, making sure that the axis of the camera is so directed that it intersects the principle object of interest.

CONCLUSIONS

THE PRESENT system of stereo-television using one camera pickup tube gives a stereo picture which has an aspect ratio of three high and two wide. This is undesirable for use in any permanent installation. Also, the field of view is very restricted, and the resolution is adversely affected.

A more desirable system would consist of the use of two television camera pickup tubes arranged side by side in a horizontal direction. The left pickup tube would supply a left-eye view to one of the receiving tubes of the dual viewer and the right pickup tube would supply the video signal for the second receiving tube.

To test adequately the possibilities of the stereo-television system as a means of seeing objects in 3-dimensional space, two mechanical master-slave manipulators were arranged so that the operator sat with his back to a wall, behind which the slave hands and the stereo-television were located (see Figure 10). The operator faced the stereo-receiver and saw a 3-dimensional image of the manipulator slave hands and objects in the work area, while with his hands in the master controls he manipulated objects in the field of view. After a few minutes of indoctrination any person with normal vision can be taught to see and manipulate the objects in view from a remote distance. In this setup the separation between master and slave was approximately three feet. This short distance was due only to the limitation of the mechanical manipulators themselves. In another setup an electrically operated manipulator was made to perform miscellaneous feats of lifting objects and pouring liquids from one beaker to another while the operator controlled its movements from another room over 50 feet away.

Sound Is Studied in New Test Chamber of M.I.T. Acoustics Laboratory

The interior of the new test chamber of the Massachusetts Institute of Technology is shown. The principles which explain how sound gets from one side of the wall to the other are being studied, as well as the use of these principles to achieve quieter, more restful homes and offices. Left to right are Dr. R. H. Bolt, director of the laboratory; Dr. J. J. Baruch, designer of the electronic equipment; and Dr. L. L. Beranek, technical director of the laboratory. The test panel, mounted on a steel frame, is set into one wall of a soundproof concrete test chamber. The inside of the concrete test room is lined with glass-fibre wedges, which absorb all reflected sound. By absorbing this sound the wedges leave the microphone free to concentrate on the noise that comes through the test panel

Dr. Baruch, who designed the electronic recording device, is watching the stylus as it draws a sound "contour map" from information transmitted automatically by a sensitive microphone moving about in the test chamber. A uniform steady sound is sent toward one side of a wall to be tested. The source of sound is an array of 256 small loudspeakers mounted close together in a panel of 16 rows of 16 speakers each. Electronic oscillators drive the speakers, which can be phased so that they all push in unison or so that some are ahead or behind others. On the other side of the wall is a microphone which picks up the sound which gets through the test sample. This automatically reports on how much sound passes through each component of the panel, sends the report to a mapping device, and automatically puts the information on a map-like plot of the test panel. The results show what parts of the panel muffle sound best. This may enable engineers to design another panel incorporating only the best features of the previous one

Analogue Computers Containing Photo Cells

E. C. KOENIG
ASSOCIATE AIEE

THE ELECTRIC analogue computer is a device for solving problems involving single-valued nonlinear parameters. Although it was built primarily for the purpose of analyzing magnetic circuits, its application can be extended to cover the solutions of other nonlinear systems. The use of the photo cell as a nonlinear element for representing nonlinear parameters of a system makes the computer relatively simple in design and easy to operate.

The photo cell has several unique features which make it very simple to use as a nonlinear element.

1. A family of curves is obtained by varying the amount of light excitation.
2. Cells to represent the same nonlinear parameter can be easily excited from the same source of light.
3. Particular curves of the families of curves of a group of cells excited from the same source can be obtained simultaneously by varying the voltage across the excitation lamp.
4. Since the light excitation circuit and the cell circuits of the analogue are completely isolated from each other, there is no problem of circulating currents through metallic connections between circuits.

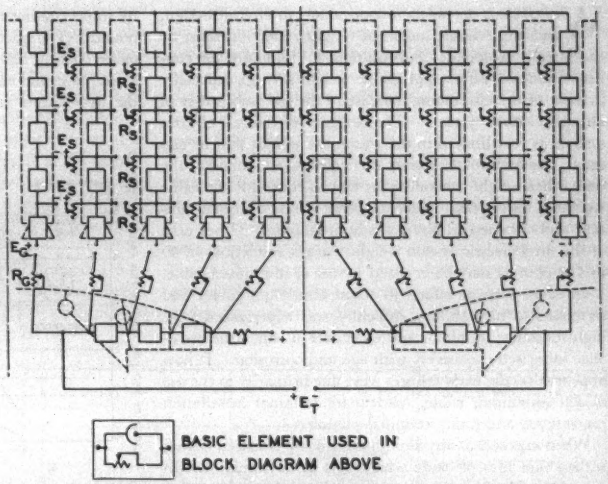

Figure 1. Analogue block diagram of the magnetic circuit of a salient-pole synchronous machine assuming only the teeth and pole head saturate

One or more photo cells in combination with one or more resistors in series or parallel and in some instances electromotive forces within the element network form the several basic elements which may be used to represent the nonlinear parameters of systems. For the case of magnetic circuits, the magnetization characteristics of magnetic material can be represented by the basic element consisting of a cell and a resistance in parallel.

There are 60 basic nonlinear elements and a number of electromotive forces and separate resistors used in the computer. The electromotive forces and adjustable resistors are not permanently connected to form a particular network but are available for inserting between the basic elements wherever required. The elements are divided into six groups with the cells of each group excited from a single light source. The unidirectional electromotive forces are supplied from half-wave rectifiers. The values of the electromotive forces can be varied from zero to as high as 2,000 volts in some cases. As many as ten separate electromotive forces can be varied simultaneously.

An example of how the basic elements, resistors, and electromotive forces can be connected on the computer to represent a magnetic circuit is shown in Figure 1. The magnetic circuit represented is that of a salient-pole synchronous machine, assuming only the teeth and pole head saturate, and the remaining magnetic material of the circuit has infinite permeability.

There nearly always will be some elements of the circuit of Figure 1 operating at the lower region of the current-voltage curve where this curve and the magnetization curve are not accurately matched. Consequently, very small errors will be introduced at any point on the calculated saturation curve of the machine, but the accuracy will tend to improve as saturation increases. The amount of fatigue or the amount the current-voltage characteristics of the cell changes with time is a function of the current flowing through the cell and also of the voltage applied. In calculating the saturation curves of electric machines at the highly saturated region, a current drop of two per cent after ten minutes is seldom exceeded.

Digest of paper 50-263, "An Electric Analogue Computer Using the Photo Cells as Nonlinear Element," recommended by the AIEE Committee on Computing Devices and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23–27, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

E. C. Koenig is with the Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

The author is indebted to Dr. Sterling Beckwith for suggestions in the preparation of this paper and for his aid in the development of the analogue computer and in applying its use to the analysis of magnetic circuits; to Walther Richter for his suggestions in the design and building of the computer; and to John Boreck and his staff for their co-operation and assistance in carrying out the laboratory work. All are of the Allis-Chalmers Manufacturing Company.

Aluminum Conductors for Aircraft

W. W. SCHUMACHER

WEIGHT is one of the major factors in aircraft design, and any reliable means of weight reduction must be thoroughly exploited. Substitution of aluminum for copper conductors offers appreciable weight savings, especially in view of the continuing increase in the size and power of aircraft electric systems. The designer of aircraft electric systems is very limited in the amount of weight that he can save. Aside from choosing the lightest components, the only other weight economy that he can control is the cable weight of his system. Since the cable weight of recent military and commercial aircraft is approximately 32 per cent of the total electric system weight, weight reductions of 40 to 100 pounds may be realized by use of aluminum cable.

In early postwar efforts to adapt aluminum cables and terminals to aircraft use, difficulty was experienced with high-resistance terminals and terminals in which the resistance increased excessively with age and corrosion. It now appears that the early failures were due primarily to the use of soft aluminum cable, inadequate terminal installation procedures, and faulty terminal plating.

When exposed to air, aluminum quickly becomes coated with a thin film of oxide which acts as an insulator. In stranded cable this oxide forms not only on the cable surface but on all of the strands as well. This causes a transverse resistance between the inner strands and the cable surface which must be overcome if satisfactory termination of cables is to be accomplished. The strands of aluminum cables that are terminated with pressure-applied longitudinally indented terminals are drastically reshaped and the oxide coating is wiped off. The removal of the oxide is enhanced by impregnating the strands with a petrolatum-zinc compound. The particles of metallic zinc break through the oxide coating and form low-resistance current paths from strand to strand and from cable to terminal. Furthermore, the petrolatum prevents reformation of the oxide which would increase the terminal resistance with age. Another practice, which has proved to be beneficial, is wrapping the cable to terminal junction with a vinyl adhesive tape. By sealing in the compound and sealing out the air the tape prevents reoxidation of the aluminum and corrosion at the cable to terminal junction.

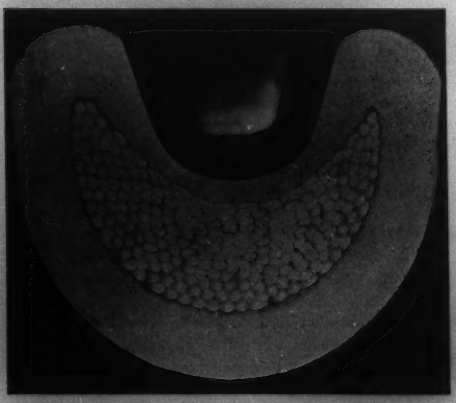

Figure 1. The contour and depth of a properly indented terminal must produce a mechanically strong connection with the optimum electrical conductivity

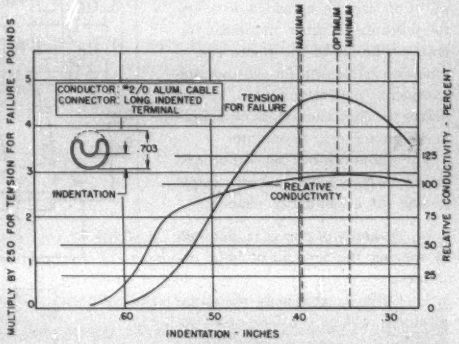

Figure 2. The effect of different indent depths for a given contour versus conductivity and tension for failure for a longitudinally indented terminal

The contour and depth of terminal indent must be coordinated to produce a mechanically strong connection with the optimum electrical conductivity and a cross section which is free of any voids. The entire surface of each strand must be in intimate contact with the surface of adjacent strands. Figure 1 illustrates the cross section of a properly indented terminal. The effect of different indent depths for a given contour versus conductivity and tension for failure is illustrated in Figure 2. The conductivity and tension for failure increases with depth of indent to a maximum and then decreases. To the left of the peak the connection fails because the cable pulls out of the terminal. To the right the cable strands are damaged by excessive pressure and break under tension. These data have been of great value in standardizing the terminal indent depth for optimum performance.

Digest of paper 50-211, "Aluminum Conductors From the Aircraft Manufacturer's Viewpoint," recommended by the AIEE Committee on Air Transportation and approved by the AIEE Technical Program Committee for presentation at the AIEE Middle Eastern District Meeting, Baltimore, Md., October 3–5, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Vibration and Fatigue Life of Steel Strand

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RECENTLY REPORTED failures of steel ground strand attributed to vibration fatigue have stimulated new effort toward probing for possible explanations of the underlying reasons for the outbreak. The study of the construction practices followed by many utilities revealed several facts: failures were more frequently reported on the higher strength grades of strand; final tensions in many cases were set at 25 per cent of rated strand breaking strength at 60 degrees Fahrenheit; experience which was gained many years ago showing the necessity of armoring conductors at the support points has not been applied generally in the case of the ground strand.

Wires comprising the galvanized strand of various grades and of type-302 stainless steel were tested in reversed bending fatigue. The results on the galvanized wires showed that the extra-high-strength galvanized grade had the highest endurance limit stress of all types tested, but when compared with the others on a basis of endurance ratio (endurance limit divided by tensile strength) this grade fell below all other grades, indicating that working stresses in the extra-high-strength grade based on a percentage of its ultimate strength should be more conservative than for the lower strength grades of galvanized strand if infinite life is to be expected. The stainless steel wire displayed a much more favorable endurance ratio despite its having a slightly higher ultimate strength than the extra-high-strength galvanized wire.

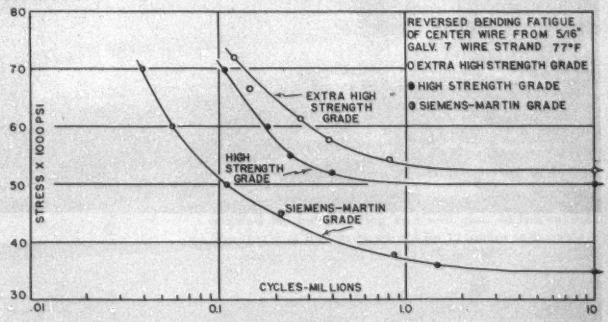

Figure 1. Reversed bending fatigue of center wire from 5/16-inch galvanized 7-wire strands at 77 degrees Fahrenheit

Investigation of the effect of operating temperature on the endurance limit of various materials which are used for strand reveals a maximum change of only about 3 per cent for galvanized wire in the range −55 to +200 degrees Fahrenheit. The change is similar for the stainless steel.

Effect of temperature variation on elastic modulus was determined experimentally for both the galvanized carbon steel and the stainless steel wires. It was found that in the case of both materials, the modulus change was approximately 1,000,000 pounds per square inch within the stated range.

Thermal expansion coefficients, important in their effect on static wire tensions, also were investigated in the temperature range from −55 to +200 degrees Fahrenheit. An example of thermal expansion in a typical 500-foot span of galvanized carbon steel strand, initially tensioned to 25 per cent of rated strength at 60 degrees Fahrenheit, will show by virtue of its expansion coefficient a tension of as much as 34 per cent of rated strength when operated at −65 degrees Fahrenheit.

Resonant frequency vibration fatigue tests on 5/16-inch extra-high-strength 7-wire strand were made to determine the effect of various initial tensions on strand life (see Figure 1), as well as the effect of applying armor rods to the support points. When conductor life was plotted as a function of vibration amplitude, it was found that the galvanized extra-high-strength-grade strand gave erratic performance under any tension. However, a definite trend of a decreased strand life (to about one-third) was experienced at a given amplitude level when the tension was increased from 25 per cent to 34 per cent of the rated strength of the steel strand.

Tests indicated that an increase of about ten times in strand life could be attained in either of two ways: by decreasing the tension from 25 per cent to about 14 per cent of rated strand strength; or by retaining the tension of 25 per cent rated strength and applying armor rods at the support points.

Laboratory and field experience both seem to indicate that serious consideration could well be given the present commonly used tension limitation of 25 per cent of rated breaking strength at 60 degrees Fahrenheit. It is felt that tensions of 20 per cent at 0 degrees Fahrenheit for extra-high-strength-grade galvanized strand would provide much more trouble-free operation than is experienced at the present.

Digest of paper 50-237, "Vibration and Fatigue Life of Steel Strand," recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23-27, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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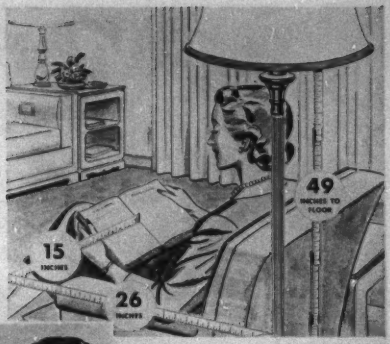
Light Conditioning Homes

FOR THE FIRST TIME a program to provide better home lighting by the use of definite basic lighting recipes has been introduced. By the end of 1951 about 10,000 demonstration homes throughout the country will be in use to show homemakers better home lighting by the use of these recipes and to acquaint them with its benefits, including easier, safer, and faster seeing and greater eye comfort and protection. The lighting recipes used in this program were originated by Eugene W. Commery, illuminating engineer in charge of the General Electric Company's residential lighting activities, and the program is sponsored by the General Electric's Lamp Department, Nela Park, Cleveland, Ohio. The entire program is based on a report developed by the Committee of Residence Lighting of the Illuminating Engineering Society entitled "Functional Visual Activities in the Home and the Location and Extent of Associated Areas to Be Illuminated" which will be published soon.

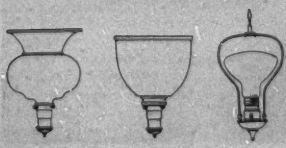
The top picture demonstrates lighting as it is now found in the living-dining area of many homes. It is provided by four portable lamps and a dining room ceiling fixture. The portable lamps are properly positioned with relation to the furniture and the seeing tasks; however, they lack bulbs of adequate wattage. The absence of general lighting makes an uncomfortable seeing situation. For purposes of this picture, hassocks were used to represent chairs on the side of the room nearest the camera. The bottom picture shows the same demonstration living-dining area after light conditioning. In addition to the four portable lamps, which now contain bulbs of adequate wattage, and the dining ceiling fixture, general lighting is provided by a room-length lighted valance and a lighted wall cornice. These serve to provide a general level of illumination, eliminating contrasts between lights and shadows. Behind the valance and cornice 20-, 25-, or 40-watt fluorescent tubes or 40- or 60-watt lumiline lamps may be used

▲ If a table lamp is to be used for illumination when reading seated in an upholstered chair, a lamp measuring from 25 to 30 inches to the top of the reflector is recommended. The height of the table on which the lamp is placed should be 25 inches. The recommended light source is a 50-100-150-watt 3-light frosted bulb or a plain 150-watt bulb for 20 to 25 foot-candles of light. The top of the diffusing bowl should be about 9 inches across, and the bottom of the shade 16 inches. The lamp should be 20 inches to the side and 16 inches in back of the reading material



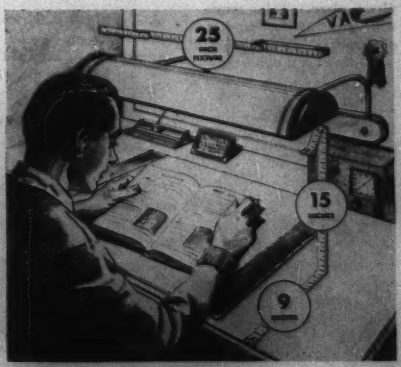
▲ For reading when seated in an upholstered chair, a floor lamp should be 15 inches to the right or left and 26 inches to the rear of the center of the reading matter. A senior floor lamp 58 to 60 inches from the floor to the top of the shade, which uses a 100-200-300-watt 3-light frosted bulb, will give 35 foot-candles of light. The bottom of the shade should be 49 inches above the floor. If desired, a junior floor lamp, a bridge lamp, or a swing-arm lamp with a white diffusing 150-watt bulb or same voltage in diffusing bowl may be used to give 20 foot-candles

▲ A pair of 66-inch torchieres with 100-200-300-watt 3-light frosted bulbs located 34 inches to the left and right of the center of the keyboard in line with the lower edge of the keyboard will give about 15 foot-candles of light for reading piano music. Shallow, white-inside, dense reflectors are the preferred type

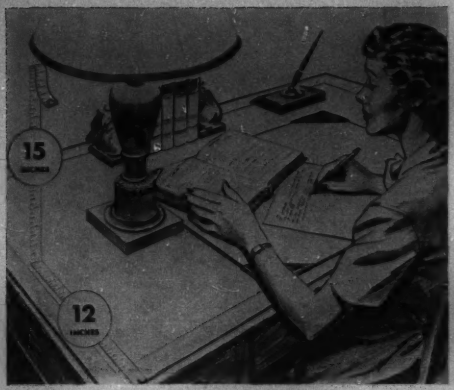


◀ Under the shade of a floor or table lamp the lighting diffuser or reflector should resemble one of these fixtures

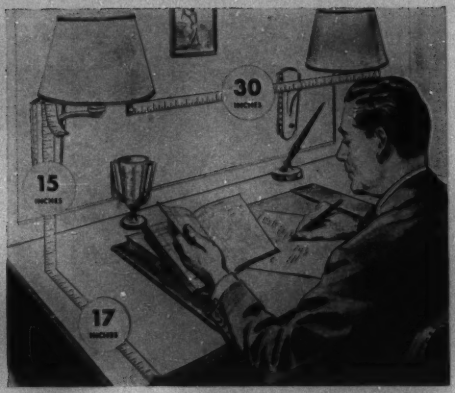
▲ A swing-arm floor lamp with a 9-inch diffusing bowl and a 150-watt bulb plus a 32-watt circline tube is recommended for hand sewing and will give 40 foot-candles. The center of the shade should be 15 inches to the side of the sewing and 12 inches toward the back of the chair



▲ Two 20-watt fluorescent lamps in a fixture with a diffusing sheet at the bottom and a translucent reflector above may be mounted 9 inches in from the front of a desk and 15 inches above the desk top to give 80 foot-candles of light for reading, writing, or drawing

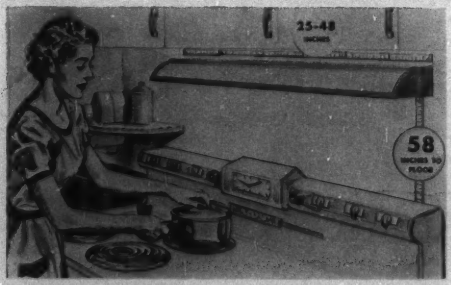


▲ When a table lamp is used on a desk, the 16-inch diameter bottom of the shade should be 15 inches above the desk top. The 50-100-150-watt 3-light or 150-watt frosted bulb should be used in a diffusing bowl and shielded by a nontransparent shade. A pastel blotter on the desk top will prevent glare from the 40 foot-candles of light



▲ Two diffusing-bowl-type wall lamps may be used above a desk to give 40 foot-candles of light. The top diameter of the bowl should be 6 inches, the bottom diameter of the shade 10 inches, and the depth of the shade 6½ inches. It is desirable to have the centers of the lamps 30 inches apart, 15 inches from the desk top, and 17 inches from the desk front

▼ An unshielded surface fixture holding two 25-watt fluorescent tubes may be attached to the ceiling over the sink and back of a shielding board between cabinets on each side of the sink or range. The shielding board will protect the eyes from the discomfort of direct glare. This setup will give 25 foot-candles of glare-free light on kitchen duties at the sink



▲ A shielded unit (25-watt fluorescent tube, two 60-watt lumiline tubes end to end, or two 60-watt frosted bulbs 18 inches apart) may be attached to the wall behind a range or sink with the bottom of the shielding about 58 inches from the floor

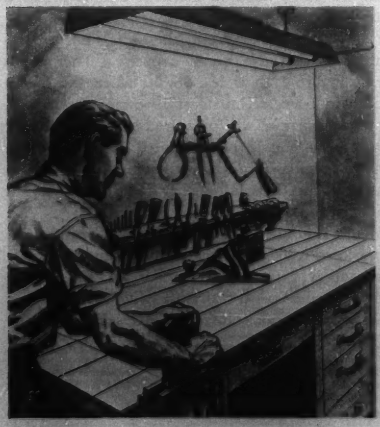
▼ To illuminate food preparation with 25 foot-candles of light, a 20-watt fluorescent tube or 60-watt lumiline tube may be attached to the wall near the bottom edge of upper cabinets. The fixture may be unshielded if the cabinets shield it from the housewife's eyes. If the lamps can be seen when seated at nearby breakfast alcoves they should be shielded

▼ To spread 20 foot-candles of light evenly on both sides and the front of the face a pair of dressing-table lamps may be used. The height of the center of the shades should be 15 to 16 inches, and the lamps should be placed 18 inches to the right and left of the center of the mirror and 6 inches from the back of the vanity. Shades should be white or pale ivory so they will not distort the color of the face. The use of 100-watt bulbs is recommended

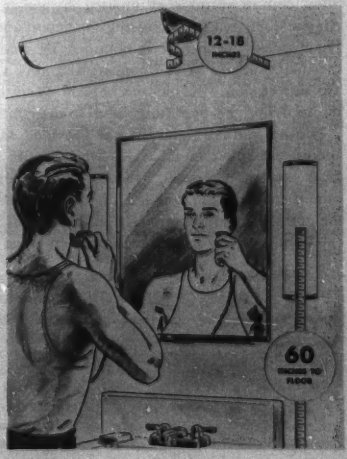
▶ For reading in bed a wall lamp may be centered above the head of the bed 30 inches above the top of the mattress. A fixture containing a 25-watt fluorescent lamp or two 40- or 60-watt lumiline lamps, of the type which will let light go up as well as down, will give 25 foot-candles of light

▶ A table lamp with a 50-100-150-watt frosted bulb in the diffusing bowl may be placed on a 28-inch bedside table. The center of the lamp should be located 22 inches sideways from the center of the book and 16 inches in back of it. The bottom of the lampshade should should be about 20 inches above the top of the mattress

▼ Lighting of a work bench may be accomplished by suspending a metal reflector shielding two 25-watt fluorescent tubes. If desired, a 12-inch-diameter round metal reflector may be used with a 150-watt silverbowl bulb. The fixture should be installed with the center 10 inches back from the front edge of the work bench. A similar fixture may be used to give 25 foot-candles of light on laundry tubs, ironing board, or ironer



▶ Three 15- or 20-watt fluorescent tubes are recommended for 30 foot-candles of bathroom lighting. A fixture should be placed on each side of the mirror, 15 inches from the mirror center. Vertical centers should be 60 inches above the floor. The third unit is mounted on the ceiling above the washstand



An Environment-Free 120-Volt D-C Limit Switch

T. R. STUELPNAGEL
ASSOCIATE AIEE

THE *H420A* switch is a newly developed high-performance hermetically sealed 120-volt d-c aircraft limit switch. This switch was specifically designed to carry $3\frac{1}{2}$ kw and to interrupt a 1.8-kw motor load, 15 times a second, for duty cycles of 15 seconds each.

Development was undertaken because no existing switch would meet these rigorous specifications and because present 120-volt d-c aircraft electric systems are in need of a reliable limit switch capable of interrupting up to 30 amperes of motor current. Aircraft electric loads of this nature now are being controlled with switch and sealed relay combinations that are inherently larger, heavier, and more unreliable than a corresponding switch. The prototype limit switch weighs one-half pound and was designed to replace a $2\frac{1}{2}$-pound sealed relay.

This switch incorporates, with basic simplicity, the following features which are considered essential, though they are not available in any other aircraft limit switch:

1. Positive mechanical separation of the contacts as a follow-up to the snap-action mechanism.
2. Eight ounces of contact pressure per contact.
3. A magnetic detent which maintains substantial contact pressure until after the mechanism trips.
4. No detectable contact bounce during switch closure.
5. Double-break permanent-magnet arc suppression.
6. A contact assembly capable of interrupting 1.8 kw of motor load one million times without failure.
7. High-temperature glass-fused mica insulation.
8. Hermetic sealing.

The mechanical features of the switch are obtained without using complicated lever and spring assemblies. Such complication is eliminated by using a one-ounce Alnico-V magnet for producing the detent and snap-action. Phenomenal cyclic rate is obtained by combining ample thermal capacity in the contact assembly with magnetic arc suppression. Rapid mechanical operation is secured by applying the operating force to the contact armature.

Positive contact separation is provided as a protection against possible contact welds which could result from a gross electric overload. If the snap-action mechanism cannot separate the contacts, the switch overtravel causes the plunger to bottom directly on the contact armature and extensions of the armature and then open the contacts with a force transmitted from the operating device.

Unlike the typical snap-action switch, the *H420A* switch maintains substantial contact pressure until after the mechanism trips. This eliminates possible destructive contact chatter as the plunger trip point is approached.

Eight-ounce contact pressure has been provided in order to circumvent the vibration, contact bounce, and surface oxidation problems encountered with switches and relays having contact pressures less than four ounces. It has been found especially desirable, on a series break device with silver-base semirefractory contact materials, to have eight ounces of contact pressure per contact.

The switch is constructed entirely of metal and a very-high-quality dielectric composed of fused mica and glass. This dielectric is superior to the usual switch insulation materials because it will stand exceptionally high temperatures and will not carbon track under repeated arcing.

Use of magnetic arc suppression for arc quenching has particular advantages in a hermetically sealed 0.1-inch gap snap-action limit switch because the increased break capacity and minimum arc energy obtainable with blowout magnets permit the design of a simpler and more compact 2-break switch which can interrupt higher energy inductive loads at a given cyclic rate.

Magnetic arc suppression has reduced effectiveness with altitude, depending to some extent upon the variables of contact separation, contact temperature, contact material, blowout field strength and location, load current, and possibly the speed of contact separation. Because mechanical restrictions limit contact separation to 0.1 inch in the *H420A* switch, hermetic sealing at one atmosphere of pressure is the most practical immediate solution to environment-free operation. When interrupting the specified 15-ampere motor load, a hermetic seal is required for reliable operation above a 30,000-foot altitude.

At one atmosphere of pressure, the switch has an unusually high 120-volt d-c break capacity. The curves presented in Figure 1 show test results when the switch was operated in 1-second bursts at 10 cycles per second. For all practical purposes, the measured arc energy during circuit interruption equals the calculated load energy and the switch arc time has a constant value for a given circuit time constant L/R. This latter characteristic provides a convenient basis for rating the switch.

Peak voltages resulting from interruption of the inductive loads never exceed 1,000 volts because the arc time increases with load energy. This characteristic of the *H420A* switch is desirable because d-c aircraft switches often cause insulation-damaging peak voltages in excess of 5,000 volts.

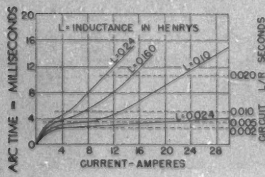


Figure 1. H420A switch break capacity. Curves obtained with an unsealed switch operating at sea-level pressure and 10 cycles for 1-second intervals. Inductance ratings based on current rise time

Digest of paper 50-203, "An Environment-Free 120-Volt D-C High Performance Limit Switch," recommended by the AIEE Committee on Air Transportation and approved by the AIEE Technical Program Committee for presentation at the AIEE Middle Eastern District Meeting, Baltimore, Md., October 3–5, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Conduction Phenomena in Gases

J. P. MOLNAR

A review is made of the processes involved in the breakdown of a gas, in which a body of neutral gas particles that acts as an insulator is changed to one containing a great many charged particles that acts as a conductor. Factors which must be taken into account in discussing these mechanisms include the gas pressure and the nature of the applied field.

THE CENTRAL problem in understanding the conduction of electricity through gases is that of finding the means by which a body of gas initially containing mainly neutral particles is converted into one with a high density of charged particles and maintained that way. It is the motion of charged particles under the influence of an electric field that constitutes the flow of electricity through a gas, exactly as in a metal conductor. In a metal conductor there is always a copious supply of electrons free to move whenever a field is applied. In the gas there is normally no such supply, only a few electrons and ions caused by the action of cosmic rays. The problem confronting the physicist is to find the mechanisms by which these few electrons and ions can be multiplied by an applied electric field to a much larger number. When such a multiplication has been effected, the gas changes its state from that of an insulator to that of a conductor, and breakdown is said to have occurred.

The mechanisms which bring about breakdown depend on a variety of factors, such as the pressure of the gas and whether the applied field is steady or alternating. In this article the detailed processes of breakdown are discussed for three cases: 1. high-frequency fields; 2. d-c fields at low gas pressures; and 3. d-c fields at high gas pressures. The processes are relatively simple in the high-frequency case and become progressively more involved for breakdown in d-c fields at low pressure and at high pressure.

MOTION OF ELECTRONS IN A GAS

THE FIRST STEP in all breakdown processes is the ionization of neutral gas atoms or molecules by electron impact. The few electrons which are created by the action of cosmic rays are accelerated by the applied electric field to a velocity sufficient to cause ionization and thereby produce new electrons and positive ions. To cause ionization the electron must have a certain minimum velocity, which for most gases corresponds to that acquired when an electron falls freely through a potential difference of 10 to 20 volts.

Normally an electron in a gas cannot fall freely through such a potential difference because it will collide with atoms or molecules on the way. Either the field strength has to be very high or the gas density very low for an electron to fall freely through such a potential difference. If a collision occurs when the electron velocity is small, the electron simply will bounce off the much heavier atom, its direction of motion being thus altered with its speed being reduced only slightly. At higher speeds which are still below the ionization limit, the collision may result in the excitation of the atom or molecule which then may radiate light. In such exciting collisions the electron will lose a large part of its original velocity. The net effect of an applied field is to increase the average velocity of any electrons present, but the many collisions with neutral particles will tend to randomize the directions of motion, and the exciting type of collisions will tend to reduce greatly the number of electrons which can attain an energy sufficient for ionization.

In addition to this random motion, there will, of course, be a small net component of drift in the direction of the applied field which will tend to sweep the electrons, new and old, to the anode and the positive ions to the cathode. This net component of drift velocity in a d-c field, though small, still makes it difficult to build up a high density of charged particles in a given volume of gas by the direct ionization process alone.

HIGH-FREQUENCY BREAKDOWN

THE SITUATION is radically changed if the electric field is alternated rapidly. Then there is not enough time for an electron to get going very far in one direction before the field reverses and drives the electron in the opposite direction. At 1,000 megacycles and a field strength of 1,000 volts per centimeter, for example, an electron in free space will execute a simple harmonic motion with an amplitude of only 0.5 millimeter. If a collision occurs during a single cycle of alternation, the net displacement of the electron caused by the field is even less. The effect of a high-frequency field is then simply to shake up the electrons in a gas; that is, to increase their random velocities but impart no net drift velocity to them.

They will move toward the walls of the container and be removed there only as a result of their random wanderings or, to use a more technical term, by diffusion. This is a much slower removal process. The density of electrons in gas-filled containers will increase indefinitely, if the rate at which new electrons are formed by ionization is greater than their rate of loss by diffusion. Thus, strangely

Fourth in a series of articles on dielectrics. See "Dielectrics in Electrical Engineering," A. von Hippel (*EE, Sep '50, pp 771–3*); "Structure and Polarization of Atoms and Molecules," J. C. Slater (*EE, Oct '50, pp8 72–5*); "Dielectric Relaxation in Liquids and Solids," C. P. Smyth (*EE, Nov '50, pp 975–80*).

Essentially full text of a paper presented at the Symposium on Dielectrics held during the AIEE Winter General Meeting, January 30–February 3, 1950, New York, N. Y. The symposium was under the joint sponsorship of the AIEE and the American Physical Society.

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enough, when we go to very high frequencies, where most electrical phenomena are more difficult to explain, the problem of breakdown in a gas becomes very simple. One must simply find the strength of the electric field which will shake up the few electrons present to high enough random velocities so that they form new electrons by ionization faster than they leak off to the walls by diffusion.

A group of physicists[1] recently formulated this problem in quantitative terms, calculated breakdown fields, and checked them against measured values. In the typical fashion of physicists they applied their analysis first to a gas which has probably no practical importance but has simpler properties for the purposes here than any other known. This gas was helium contaminated with a small amount of mercury vapor. They have named it Heg-gas. (Later they applied the method with success to pure hydrogen also.[2])

The analysis begins with a calculation of a distribution function of electron velocities. Such a distribution function gives the fraction of the electrons present which will have velocities in any given range. These distribution functions are not particularly interesting to look at. If, for example, one plots the distribution function for total velocity against the velocity, the curve starts from zero at zero velocity, because no electrons are standing perfectly still, rises to a maximum value, and decreases to zero at high velocities. The theorist, however, finds that with the aid of these functions he can compute the ionization rate from the part of the curve above the critical velocity necessary for ionization, and the diffusion rate from the complete curve.

To calculate a velocity-distribution function one must take into account all the factors which alter the velocities of electrons. These are: 1. collisions with atoms, either elastic or inelastic; and 2. acceleration of the applied field.

In the case of Heg-gas, the mercury atom concentration is so low that one can neglect electron collisions with these atoms and be concerned only with the collisions between electrons and helium atoms. Elastic collisions between electrons and helium atoms have been carefully studied, and reliable data are available describing the properties of such collisions. The inelastic collisions are less easy to introduce into the theory, and also the available experimental data are less satisfactory. It is here that the mercury vapor comes into the picture.

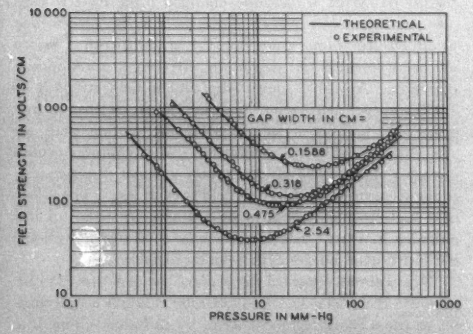

Figure 1. Calculated and observed field strengths required for breakdown as a function of pressure in Heg-gas at 3,000 megacycles for plane-parallel electrode geometry, as given in reference 1

The lowest excited state of helium is metastable, which means that if a helium atom is raised to this state it will stay there for a considerable time, up to thousands of microseconds. (Normally an atom remains in an excited state for less than one-tenth microsecond.) During these thousands of microseconds the metastable helium atom will collide with many thousands of normal helium atoms and remain unaffected. If, however, it collides with a mercury atom a strange thing happens. The energy of excitation of the helium can be transferred to the mercury atom, and this is enough to ionize it. Thus an electron collision which raises a helium atom to its first excited state results in the production of an ion-electron pair—not immediately, but in a matter of tens or hundreds of microseconds. Furthermore, this excitation process is a highly probable one in helium, so that few electrons have an opportunity to get more than the amount of energy necessary to accomplish this process. Hence excitations to higher, nonmetastable states, or direct ionizations, may be neglected.

With the electron-atom interactions simplified, an exact solution of the distribution function could be carried out. The problem was still not simple, but by ingenious juggling of the equations a solution was found in terms of confluent hypergeometric functions. From the distribution functions the rate of electron production by ionization and the rate of loss by diffusion were directly calculable. For any given gas pressure these are both dependent on the rms value of the electric field strength. To find the breakdown field it was only necessary to find that value of the field at which the rate of diffusion loss equalled the production rate.

The results are shown in Figure 1. Here breakdown field is plotted against pressure for several different electrode spacings, all for 10-centimeter microwaves. The breakdown field depends on the electrode spacing because of the dependence of the rate of diffusion loss on the spacing. These losses are greater for closely spaced electrodes; hence the fields required for breakdown decrease as the spacing is increased. The solid lines show the theoretical values, the circles the experimental points. The agreement, on the average, is within ±3 per cent.

The experiments involved in obtaining the measured values required careful planning. Here, of course, the developments in the radar field during the war provided the basis of instrumentation by which accurate field measurements could be made at microwave frequencies. A tunable continuous-wave magnetron was used for a source of power, a resonant cavity was used for the breakdown chamber, and a bolometer was used for power measurements.

D-C BREAKDOWN AT LOW PRESSURES

Breakdown in d-c fields for gas pressures in the range of millimeters of mercury is described by the so-called Townsend mechanism, after the English physicist who

first correctly identified the main features of the process almost 50 years ago.

The process of breakdown when the Townsend mechanism is operating is illustrated in Figure 2. Assume a chance electron is available near the cathode sometime after the field is applied. This will be drawn to the anode. On the way it will ionize atoms which will have progeny electrons that also cause ionizations. The electric field also acts to draw the positive ions toward the cathode. They move more slowly because of their greater mass, but in about ten microseconds they too will be removed. If that were the whole story, a current meter in the external circuit would indicate simply a series of pulses corresponding to the chance appearance of electrons by cosmic rays.

There is another process occurring, namely, an emission of electrons from the cathode when the ions strike it. This is a relatively inefficient process with only a small fraction of the ions producing an electron. However, it makes a profound difference in the ionization process. If, for example, one electron is emitted for every ten ions which strike the cathode, and, furthermore, if the original electron in its course across the gap gives birth directly or through its progeny to ten positive ions, then there is a mechanism by which the original electron can be replaced. If the ionization is increased slightly so as to give a little more than ten ions (say, by increasing the applied potential), the density of electrons will increase and breakdown ensue.

The Townsend mechanism of d-c breakdown at low gas pressures appears well established. This was accomplished, not by checking observed breakdown voltages against calculated ones, as described for the high-frequency case, but rather by measuring ionization rates in the gas and electron emission efficiencies at the cathode and using these experimental data to compute breakdown voltages. These data are obtained by studying the current multiplication in gas-filled tubes at voltages below breakdown. The experimental tubes on which such studies have been made are in principle very much like gas-filled phototubes. Rather than depend on the chance appearance of electrons, a steady supply is provided by shining light on the cathode, which gives rise to a current of photoelectrons. If one then investigates how the amplification of this primary electron current varies with applied voltage and with the electrode spacing, it is possible to separate the part of the amplification that arises from the ionization in the gas and the part which arises from the emission of new electrons at the cathode by ion bombardment. When the ionization rate and the electron emission efficiency are thus determined, the breakdown voltage is directly calculable and checks the experimental values very well.

Although the mechanisms here have been correctly identified, a more satisfactory solution of the problem requires that the observed ionization rates be checked against values calculated from first principles. This has been attempted with only fair agreement between theory and experiment. Perhaps the success obtained in the high-frequency case will inspire others to try to improve the existing calculations for the d-c case.

Our understanding of the second part of the Townsend mechanism, namely, the process of electron emission at the cathode, is in a much less satisfactory state. It is a problem of practical importance, too, because the same process of electron emission also takes place in glow discharges. Thus, the operating characteristics of glow discharges depend very much on the efficiency of this emission process, which varies widely among cathode materials.

So far, it has been stated here that the emission is produced only by ions. In fact, the ions produce only part of the emission, and the metastable atoms and photons which also are generated in the gas make a substantial contribution. The first question which arises is what fraction of the emission is produced by the ions, by the metastables, and by the photons. This obviously will depend on the relative number of these particles arriving at the cathode, as well as their efficiency of electron emission.

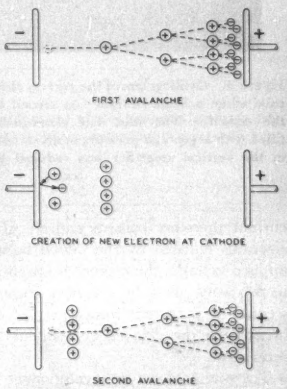

Figure 2. Development of breakdown when the Townsend mechanism is operating. (Top) Ionization caused by a single electron crossing the gap. (Center) Creation at the cathode of a new electron produced by the impact of an ion. (Bottom) Ionization resulting from the newly created electron

Experiments have been conducted recently in an attempt to solve this problem. Use is made of the difference in time required for each of the particles once formed to get to the cathode. The ions being drawn by the electric field will take of the order of ten microseconds. Metastable atoms are neutral particles and move only because of their temperature motion. They will take, on the average, about 1,000 microseconds. The photon times are harder to specify. If we assume they move with the speed of light, they will take less than 0.001 microsecond. Actually many of the higher energy photons (which are especially efficient photoelectrically) will be absorbed and re-emitted by neutral atoms in the gas many times on their way to the cathode, thus increasing their transit time to as much as 40 microseconds.

The method of experiment is to study the transient character of the current through the experimental tube when the light which produces the primary photocurrent is pulsed. In Figure 3 oscillograms are shown of the current recorded in such an experiment for a light pulse of five milliseconds' duration. The upper left-hand trace shows the current through the tube for a low applied voltage, for example, ten volts, which is so low that there can be no excitation or ionization of the argon gas, and the

Figure 3. Oscillograms of the current through a gas-filled phototube when a beam of light $^1/_{200}$ second in duration is shone on the cathode. The tube has plane-parallel electrodes and is filled with argon at a pressure of about one millimeter. The gain in the vertical amplifier was reduced for the higher voltage traces

current therefore consists entirely of the primary photoelectrons released by the pulsed light beam. For higher applied voltages the current is amplified, but this happens in two ways: first, by a current component in phase, and, second, by a current component which is delayed. Near breakdown the delayed component becomes particularly prominent.

The origin of the slow component is the electron emission at the cathode produced by the metastable atoms. These metastable atoms are slow to find their way to the cathode and thus cause the delayed nature of this component. On the time scale of these traces, the other multiplication processes appear instantaneous and are not separable.

To resolve these processes one must make observations on a microsecond, rather than millisecond, time scale. The current observed on such a time scale when the Townsend discharge is initiated with a light pulse one-tenth microsecond in duration is shown in Figure 4. The interpretation of this pattern is more involved than that shown in Figure 3, but a significant point to note here is the sudden drop in current seen at ten microseconds. This drop coincides with the arrival at the cathode of the ions formed near the anode. The current drops sharply because the complete removal of the ions formed by the initial electron avalanche results in a sudden drop in the electron emission produced by these ions at the cathode.

From a quantitative analysis of patterns of this kind, as well as those shown in Figure 3, it has been found that the ions contribute about two-thirds of the emission, the metastables about one-third, and the photons just a few per cent. These figures refer to conditions of field strength and gas pressure close to those of interest in glow discharges. For lower field strengths and higher pressures, the role of the photons becomes more important.

The mechanism of emission of electrons by the photons is, of course, just the well-known photoelectric effect. The mechanism of emission by ion or metastable impact is much less well understood and still remains a challenge to the physicist. The main experimental difficulty in studying these processes is the sensitivity of the phenomena to the detailed nature of the cathode surface. Thus experimenters in this field must exercise extreme care in preparing the surfaces being studied if meaningful interpretations are to be made of their measurements.

D-C BREAKDOWN AT HIGH PRESSURES

A SECOND MECHANISM of d-c breakdown, the streamer mechanism, is found to be operative at higher gas pressures, for example, in air at atmospheric pressure. The breakdown process is characterized by the sudden formation of a channel of ionization having a small cross-sectional area. It is commonly called a spark. The breakdown voltage for sparks in air does not depend on the nature of the cathode surface, and the entire process can take place in a time less than 10^{-8} second, both of which observations rule out the Townsend mechanism.

To understand this type of breakdown it is instructive to consider what happens when the Townsend mechanism is assumed to be operating and voltages above the breakdown value are suddenly applied to a gap. In Figure 5 charge and potential distributions are shown schematically for small and large overvoltages. The upper left diagram shows the distribution of charge in the gap with a

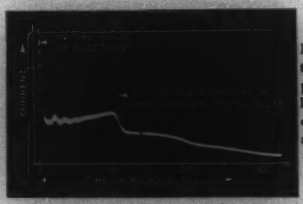

Figure 4. Current through a gas-filled phototube when a light beam is shone on the cathode for about 0.1 microsecond

Courtesy of J. A. Hornbeck

small overvoltage just after a single chance electron starting from the cathode completes its journey across the gap. The density of ionization will, in general, be so small that the distribution of potential across the gap will not be distorted appreciably by this single avalanche (Curve 1 on potential distribution curve). Since the ions move out of the gap so much more slowly than the electrons, subsequent electrons starting from the cathode will leave behind positive ions whose charge will add to that left by the first electron, so that the potential distribution will subsequently be distorted to that of Curve 2 and then Curve 3. The development of steeper gradients in the potential near the cathode makes for more efficient ionization, and the charge density in the gap then increases even more rapidly. The increased conductivity of the gas, however, results in voltage drops in the external circuit, so that a lower voltage is available across the gap. The discharge then will find a stable operating condition, Curve 4, in the form of a glow or arc discharge.

When a much higher voltage is applied suddenly, the charge density of ions and electrons in a single avalanche

may itself be large enough to disturb the applied field appreciably. This effect will be enhanced if the gas density is high and therefore it prevents rapid diffusion of the electrons. The potential distribution now will have both a negative and a positive curvature corresponding to regions of positive and negative net space charge. Thus the field is enhanced at both the front and rear of the ionized region. When this happens the region of ionization is rapidly propagated both forwards and backwards, and a visible channel, called a streamer, is seen. The streamer propagates itself so rapidly that the only known mechanism available to explain its velocity is that of photoionization. High-energy photons generated along with the ions are thought to move with the speed of light and ionize the molecules behind and ahead of the region first ionized. New avalanches are created very soon in the enhanced fields, and a channel filled with charged particles bridges the gap.

It is obvious that the operating mechanism of breakdown will shift continuously from the Townsend to the streamer mechanism as the amount of overvoltage is increased. For breakdown in air a number of factors combine to limit the range of operation of the Townsend mechanism to a very small value. Among these factors are the low electron emission efficiencies of most cathode materials by ion bombardment when exposed to a gas containing oxygen and the low diffusion rate of particles in a gas at atmospheric pressure. The former effect requires a large amount of ionization even to get breakdown by the Townsend mechanism, while the latter effect tends to keep the ions and electrons concentrated in a small volume, so that space-charge distortion of the field is more easily accomplished.

The breakdown of overvolted gaps has been known to take place in the order of 10^{-8} second for over 20 years. Accurate measurements were not available until recently when a micro-oscillograph capable of a time resolution in the range of 10^{-10} second was applied to this problem.[3] The difficult experimental problem of generating voltage pulses having a rise time of 4×10^{-10} second was solved. Figure 6 shows traces of the voltage across the test gap. The finite rate of rise is caused by the characteristics of the voltage generating circuit. The drop in voltage is caused by the breakdown of the gap, and the delay in its occurrence is seen to depend on the value of the applied field.

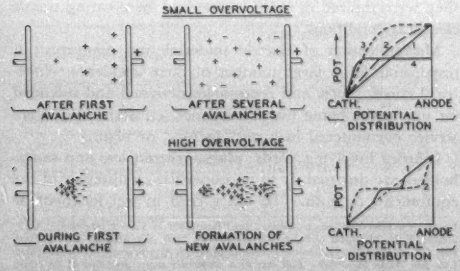

Figure 5. Charge and potential distribution in a gap at small and large overvoltages

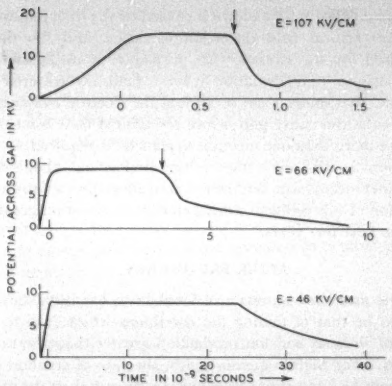

Figure 6. Traces of oscillograms of the potential across a test gap in air for large overvoltages, according to reference 3

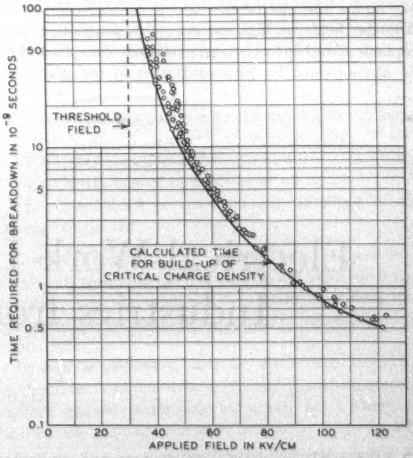
THRESHOLD FIELD
CALCULATED TIME FOR BUILD-UP OF CRITICAL CHARGE DENSITY
TIME REQUIRED FOR BREAKDOWN IN 10^{-9} SECONDS
APPLIED FIELD IN KV/CM

Figure 7. Time required for breakdown of a gap in air versus applied field, according to reference 3. The circles are experimental points, while the curve represents the time calculated for a single electron to produce an ionization density which gives rise to a space charge field equal in strength to the applied field

Figure 7 shows values of the time measured for breakdown to occur plotted against the value of the applied field. The times are seen to vary from less than 0.001 microsecond at high fields to 0.1 microsecond near the threshold value of the field. The solid curve is a calculated curve of the time required for a single electron to build up an ionization density which will produce a space-charge field equal in magnitude to that of the applied field. For high field strengths it can be seen that the calculated curve fits the experimental values well, thus suggesting that

the main delay in breakdown is caused by the time required for this critical field distortion to occur, and the time required for the streamers to propagate is negligible in comparison. The deviation at lower fields is attributed to the fact that under these conditions the electron avalanche may cross the entire gap before the critical field is set up. Hence more than one electron avalanche is required.

There is still much that is not understood about the streamer mechanism, but the research effort directed toward solution of this problem should clarify the situation greatly in the next few years.

AFTER BREAKDOWN

THE ESSENTIAL PROBLEM of breakdown has been shown to be that of finding the conditions which lead to a rate of electron and ion production greater than the rate of loss. For high-frequency fields, the rate of creation of electrons by ionization was seen to be greater than the rate of loss by diffusion. For d-c fields at low pressure an electrode effect was added, namely, the emission of electrons at the cathode by ion, metastable, and photon bombardment. The electron emission here must be adequate to make up for losses to the anode.

For d-c fields at high pressure the situation is more complicated and involves a space-charge distortion of the field accompanied by photoionization in the gas.

When conditions for charge multiplication are met in any of these cases, the density of charged particles in a given volume will rise by a large factor, 10^{12} or more, but obviously the multiplication must stop somewhere. The upper limit is set by a number of factors. First of all, there is a limit to the number of neutral gas particles present to be ionized. This is a theoretical limit rarely reached. More often the upper limit of ionization is set by the voltage drops in the external circuit, which decrease the applied potential available across a gap, and by the development of space-charge effects which upset the original field distribution. These last two factors usually combine to form a stable operating condition in which a self-maintained discharge, such as a glow or an arc, is set up between the electrodes. To understand these operating discharges one must follow ionization effects, diffusion effects, electrode effects, and space-charge effects just as has been done in the breakdown problem.

REFERENCES

1. High-Frequency Gas Discharge Breakdown in Helium, **A. D. MacDonald, Sanborn Brown.** *Physical Review* (New York, N. Y.), volume 75, pages 411–8, February 1, 1949.

2. High-Frequency Gas Discharge Breakdown in Hydrogen, **A. D. MacDonald, Sanborn Brown.** *Physical Review* (New York, N. Y.), volume 76, pages 1634–9, December 1, 1949.

3. Impulse Breakdown in the 10⁻⁸-Second Range of Air at Atmospheric Pressure, **R. C. Fletcher.** *Physical Review* (New York, N. Y.), volume 76, pages 1501–11, November 15, 1949.

Electrical Work Injuries in California Industries from 1940 to 1949

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ASSOCIATE AIEE

EXPOSURE to electric installations and equipment in places of employment in California resulted in injury to 4,851 persons during the ten-year period from 1940 to 1949 inclusive. This number includes 380 fatal injuries; 1 out of every 13 electrical injuries resulted in death.

This ratio is fifty times higher than that for all California work injuries requiring medical attention reported for the year 1949. Of about 430,000 such injuries, 656 were fatal, or a ratio of 1 death to every 655 injuries.

These figures, compiled from reports of physicians, surgeons, insurance companies, and employers operating under provisions of the California Workmen's Compensation Act, do not include either injuries which happen to the public or industrial injuries requiring first-aid treatment only.

A study of these reports shows too many cases where inexperienced employees and novice electricians either were making electrical repairs or adjustments at the time they were injured or were responsible for creating unsafe electrical conditions.

Misapplication of electric material and equipment is responsible for a large number of these accidents. Electrical cords, plugs, and receptacles designed and intended for use in the home usually will not withstand the severe service encountered in a mill, factory, or plant.

Injuries involving cords, plugs, receptacles, and lampholders are due mainly to improper use or disrepair of the equipment, or both. To use a cord in wet locations or

Fourth in a series of articles on safety. See "Perception of Electric Currents," C. F. Dalziel, T. H. Mansfield (*EE Sep '50, pp 794–800*), "108 Are Missing," E. G. Hunt (*EE Oct '50, pp 919–21*), "Safety Testing of Electronic Equipment," O. G. Wedekind (*EE Nov '50 pp 997–1000*). Full text of a conference paper presented at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950.

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near grounded surfaces, when it is intended for use in dry locations where carpets, linoleum, and hardwood floors provide insulating surfaces, is to invite trouble. Defective cords with bare spots or protruding strands should not be merely discarded but destroyed, or they may eventually find their way back into service. Rubber deteriorates and becomes brittle with age. Plugs break and expose live parts.

Motor branch-circuit disconnecting switches are intended for use when it is necessary to work on the motor or its control equipment, or to disconnect branch-circuit fuses so that the fuses may be removed safely. Too often these switches are used as motor control devices, and unless they are of the motor-circuit or horsepower-rated type they should not be used as motor control devices, especially for larger size motors. Switch explosions cause many painful injuries.

Persons contacting or bringing conducting material into contact with high-voltage lines produce the greatest percentage of fatalities in California, as far as electrical work injuries are concerned. Contacting high-voltage lines with mobile cranes, portable well-drilling rigs, orchard spray rigs, and other movable equipment caused one out of every three persons injured in this way to lose his life. The extreme hazard of this type of accident resulted in an addition to the California Penal Code in September 1947, making it a misdemeanor to operate, place, erect, or move any tools, machinery, equipment, material, building, or structure within six feet of high-voltage conductors. Widespread publicity and education on the subject and warning to operators working in the vicinity of high-voltage lines have helped to cut down injuries and fatalities, but the figures are still high.

Most of those injured while using portable tools suffered severe electrical shock, with many rendered unconscious. The necessity for the proper grounding and careful maintenance of portable electrical tools and associated wiring is plain.

A greater percentage of occupational deaths are due to electrical causes than to any other single hazard. The highest number of fatalities in electrical accidents occurs when people contact or bring conducting material into contact with high-voltage lines. Many other accidents are caused by the misuse of material and equipment.

In Table I an attempt has been made to break down electrical injuries into a minimum number of groupings according to the apparatus or equipment involved. The table indicates where particular attention should be directed, as far as apparatus and equipment are concerned, to reduce electrical accidents and injuries.

Details which cannot be incorporated in a table of this sort include:

1. Lack of adequate work space around equipment.
2. Defective insulation.
3. Broken, burned, wet, or damaged parts.
4. Inadequate guarding of exposed energized parts.
5. Use of unsafe or defective tools.
6. Use of tools in an unsafe place.
7. Use of tools in an unsafe manner.
8. Use of equipment not suitable for the application.
9. Lack of maintenance contributing to or causing unsafe electrical conditions.
10. Failure to use proper personal protective equipment.
11. Use of unsafe or defective personal protective equipment.
12. Failure of workmen to de-energize equipment, or their failure to lock switches or circuit breakers in the open position.
13. Unsafe position assumed by injured.
14. Unsafe acts of injured, or of others.
15. Unqualified person operating, installing, or maintaining equipment.

Electrical accidents and injuries will be reduced greatly if only safe equipment and apparatus are used, are installed properly, and are maintained in good condition, and if live parts are not exposed to contact or mechanical injury of any sort.

It will be necessary, too, for all persons engaged in electrical work to maintain safe practices and be constantly vigilant against performing an unsafe act. There must be a continuing and increasing interest in safety in electric installations, from the design engineer to the workmen installing, operating, or repairing equipment.

Under the Labor Code, the Division of Industrial Safety has the power, jurisdiction, and supervision over every place of employment in California which is necessary to enforce adequately and administer all laws and lawful orders requiring the protection of the life and safety of every employee in such places of employment. The Division is doing all it can to reduce industrial accidents to a minimum, through education, enforcement, and engineering advice.

Table I. Reported Electrical Work Injuries—1940 to 1949

	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949
Rotating electric equipment	20	13	15	31	22	12	8	13	14	13
Transformers and stationary converters	3	1	4	5	6	1	2	1	2	6
Portable cords, plugs, extensions	28	19	43	75	49	44	27	59	74	88
Low-voltage conductors—in metal raceways, overhead lines, bare conductors in buildings	40	29	43	45	71	45	48	98	24	22
High-voltage conductors—overhead lines	62	49	65	53	43	51	55	117	82	94
High-voltage conductors—in metal raceways and in buildings	11	14	11	15	3	1	9	6	5	4
Conductors—information not available	7	6	20	26	15	16	6	5	1	124
Switches, fuses, cutouts	108	47	91	124	89	76	69	111	146	131
Circuit breakers and motor starters		3	1	1	1	7	2	10	3	11
Control equipment—electronic, relays	3	2	5	13	9	7	7	6	3	10
Electrolytic equipment—storage batteries	3	1	10	1			1	1	1	1
Heating appliances, welders	7	7	11	36	12	7	5	5	8	17
Lighting and signs	12	8	16	13	11	8	10	10	13	23
Portable electrical tools	20	9	42	61	87	42	20	53	83	61
Electric apparatus not elsewhere classified	25	19	30	26	31	22	23	42	296	88
Information not available	40	20	52	55	41	22	13	35		
Total accidents	389	247	459	580	490	361	305	572	755	693
Total fatal	36	32	32	38	35	32	28	57	48	42

Integral Controller for Carrier-Type Servomechanisms

R. L. COSGRIFF

SATISFACTORY integral controllers and integrators for use in d-c servo systems and computers now exist. Unfortunately good counterparts do not exist for use in a-c servo systems and computers. Band-pass filters may be used, but they are unsatisfactory if the carrier frequency changes. The usual integral controller consists of a phase-sensitive detector which converts the a-c input signal into a direct voltage. This direct voltage is applied to a d-c integral controller and the output of this controller is remodulated. Often drifts of the detector and modulator of this last system introduce more error than is desirable.

The 2-phase induction motor system herein described shows promise of becoming a satisfactory a-c integral controller. This device consists of a small 2-phase motor driving two large inertia disks and an a-c tachometer. The motor is excited in such a manner by the associated amplifiers that the acceleration of the rotor assembly is nearly proportional to the input signal. The velocity of the rotor $d\theta/dt$ and the output voltage of the tachometer are then nearly equal to the time integral of the input signal I_a. A block diagram of this system is shown in Figure 1.

The range and usefulness of this controller are extended by supporting the rotor with an air bearing to eliminate all friction except viscous friction and by a special nonlinear amplifier which linearizes the speed-torque relationship of the 2-phase motor.

It can be shown that the speed torque equation of a 2-phase motor becomes approximately

$$T = K\left(\omega_0 I_x I_y - \frac{I_x^2 + I_y^2}{2}\frac{d\theta}{dt}\right) \qquad (1)$$

when the effective rotor resistance becomes large. In this equation I_x and I_y, the two currents flowing in the two stator windings of the motor, are in phase quadrature. The current I_y is held constant while the current I_x is proportional to the input signal plus the output of the nonlinear amplifier. When the gain of this nonlinear amplifier, which amplifies the output of the tachometer, is $G(1+\beta I_x^2)$ where G and β are constants, the equation of motion is

$$J d^2\theta/dt^2 = K' I_a \qquad (2)$$

where J is the inertia of the rotor system, I_a is the input signal, and K' is a constant. Since equation 2 indicates that the acceleration of the rotor is directly proportional to the input signal I_a, the rotor velocity and the tachometer output voltage are proportional to the time integral of the input signal I_a.

The mathematical expression given by equation 2 is based upon a perfect nonlinear amplifier and a simplified speed-torque relationship, and as such is only an approximation of the actual operation which takes place. Fortunately this relationship is quite accurate. Tests indicate that the Q of a band-pass filter equivalent to this controller would have a value of over a million when the carrier frequency is 400 cycles. This corresponds to a low-pass filter with a passband of less than one cycle per hour.

In many cases simplified versions of this controller may be used as integral controllers. For example, a conventional 2-phase motor which will nearly maintain speed when one phase alone is excited may be used as an integral controller. The terminal voltage of one phase of this simplified controller is constant and the second phase is excited by an amplifier with degenerative current feedback. The output terminal voltage of the amplifier, the output of the integral controller, is proportional to the sum of the input voltage and a voltage nearly proportional to the velocity of the rotor. Because of the nonlinear characteristics of this type of motor, the characteristics of the controller are not linear; however, good results may be expected at values of $d\theta/dt$ less than 25 per cent of the synchronous speed ω_0.

If the motor of the simplified controller is connected in a bridge circuit, the voltage proportional to the input voltage may be nearly eliminated if desired and the output voltage will be approximately the time integral of the input signal. In these simplified controller arrangements the nonlinear effects of conventional bearings may be minimized by increasing the inertia of the rotor to as large a value as is practical. The performance of the compensated integral controller is better than is required for most servo systems; it is actually an excellent integrator. It may be simplified for practical applications.

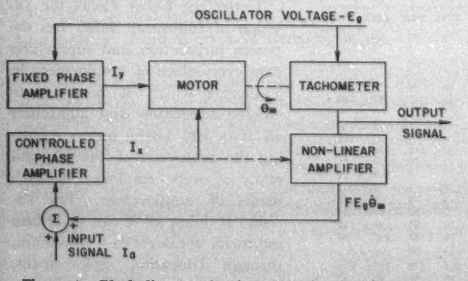

Figure 1. Block diagram showing method of exciting motor

Digest of paper 50-219, "Integral Controller for Use in Carrier-Type Servomechanisms," recommended by the AIEE Committee on Feedback Control Systems and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23–27, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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This paper is based on work done for the Air Forces at the Airplane Division of the Curtiss-Wright Corporation. The material was also used by the author in his Master's Thesis at the Ohio State University. The author is indebted to Dr. E. H. Gamble, J. R. Campbell, R. Geiger, and W. Horton of the Curtiss-Wright Corporation and Professor C. E. Warren of the Ohio State University for their helpful guidance and assistance.

Rolling-Ball Analogue of Coupled Circuits

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MEMBER AIEE

AN ELECTRIC SYSTEM consisting of two inductance-capacitance loops with negligible resistance, and inductively coupled together, has a dynamic analogue in the form of a freely rolling ball on an elevated surface, an example of which is sketched in Figure 1. The time integrals of the loop currents (q_1 and q_2) are used as displacements along co-ordinates x_1 and x_2, with the loop currents themselves analogous to the velocity of the ball along those co-ordinates. The magnetic field energy becomes analogous to the kinetic energy of the ball if the scales of the co-ordinates are made proportional to the square roots of the corresponding self-inductances, and x_1 is inclined with respect to x_2 at angle β, the angle whose cosine is the coefficient of coupling.

The height of the surface, and hence the potential energy of the ball, is made proportional to the dielectric field energy at each co-ordinate position. Contours of dielectric field energy are concentric ellipses, the axes of which also are known as the normal co-ordinates, y_1 and y_2. The angle separating y_1 from x_1 is found as follows:

$$\tan 2\alpha = (\sin 2\beta) / \left\{ [(L_1C_1)/(L_2C_2)] + \cos 2\beta \right\}$$

General motion of the ball on the surface may be resolved into two independent harmonic motions (ω_1 and ω_2) parallel to the normal co-ordinate axes; this is illustrated in Figure 2, which shows the response of the circuit with the initial conditions of both capacitors charged but no currents flowing. The initial charges are scaled on the x_1 and x_2 axes, with oa equal to $q_1(0)\sqrt{L_1}$ and ob equal to $q_2(0)\sqrt{L_2}$. A parallelogram is formed by drawing bc parallel to oa, and ac parallel to ob. The location of the ball at point c, with no initial velocity, represents the initial conditions. Line cd is drawn perpendicular to normal co-ordinate y_1, and ce perpendicular to y_2.

Line od is $y_1(0)$, the amplitude of the cosine oscillatory motion in the analogue with frequency of $\omega_1/2\pi$, and oe is $y_2(0)$, the amplitude of the cosine motion with frequency of $\omega_2/2\pi$. Because there are no initial currents, the amplitudes of the sine oscillations are zero.

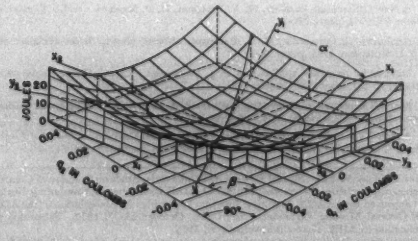

Figure 1. Isometric projection of part of the analogue surface

The amplitude of each frequency component appearing in e_1 may be found by drawing lines df and eg parallel to the x_2 axis.

$$e_1 = (of/C_1\sqrt{L_1}) \cos \omega_1 t + (og/C_1\sqrt{L_1}) \cos \omega_2 t$$

Similarly, the amplitudes of the two components in e_2 may be found by drawing dj and eh parallel to the x_1 axis.

$$e_2 = (oj/C_2\sqrt{L_2}) \cos \omega_1 t + (oh/C_2\sqrt{L_2}) \cos \omega_2 t$$

The path of motion is limited to the rectangle $ckmn$, which is symmetric about the y_1 and y_2 axes. If the ratio

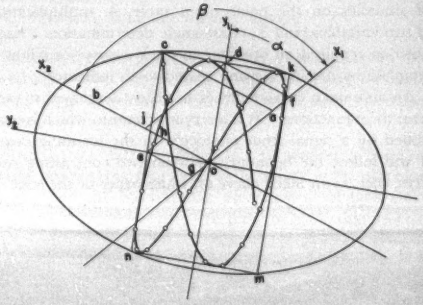

Figure 2. Ball path analogous to circuit behavior for initial conditions of both capacitors charged but with no initial currents. Circled points correspond to intervals of 0.001 second in circuit response

ω_1/ω_2 is irrational, the path of motion eventually will pass infinitesimally close to every point within this rectangle; should the frequency ratio be rational, the path will assume a repetitive pattern.

The general plan followed here for deriving an analogue should be applicable to any dynamically conservative electric or mechanical system with two degrees of freedom, and should be of aid in the interpretation of transients in such systems.

By a suitable selection of the vertical and horizontal scales, a physical model may be designed with a known ratio between its time scale and that of the original circuit. Such models, used in conjunction with top-view plots of ball paths, probably would furnish the best educational means of applying the theory developed here.

Digest of paper 50-245, "Transients in Coupled Inductance-Capacitance Circuits Analyzed in Terms of a Rolling-Ball Analogue," recommended by the AIEE Committee on Basic Sciences and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23-27, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Special Devices for Differential Analyzers

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SEVERAL PAPERS have been written[1-5] describing the differential analyzer and the complex engineering problems which can be studied with it. The range of the analyzer is being extended continuously by the development of special devices which will generate auxiliary functions and assist in the representing of physical detail, thus, in effect, increasing the number of integrators available for the solution of a given problem.

The initial installation of the analyzer shown in Figure 1 included provisions for generating many functions without the aid of integrators. These functions were as follows: 1. curve input, 2. vector summation, 3. generation of sinusoids on the polar input table, 4. multiplication of two variables, and 5. phase-angle determination. Each function required an operator to track a curve or follow a template by turning a crank geared to an indicator.

An automatic curve follower has been developed to perform these functions. It is a servomechanism which is controlled by a signal from photocells in the scanning head. It will follow the boundary between two contrasting surfaces, such as an inked curve on white paper or the edge of a template. Figure 2 illustrates the use of the curve follower for the automatic tracking of an input function.

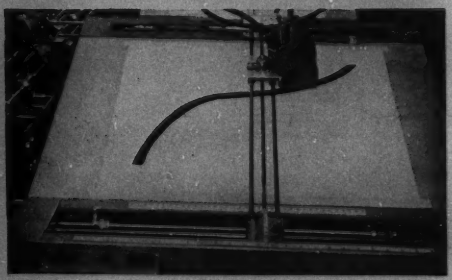

Figure 1 (top). View of the differential analyzer in operation

Figure 2 (bottom). Input table arranged for automatic curve following

Additional devices which have been developed include the following: 6. gear-ratio selector, 7. remote indicator, 8. transportation lag device, 9. recording counter, 10. deadband units, and 11. disconnect units.

By means of the gear ratio selector it is possible to change from one set of conditions to another without stopping the analyzer. This is a convenient device for the representation of saturation, ceilings, overriding signals, and changes in system gain. The principle used involves two differential gears and an automatic shaft-locking device.

Selsyns have been used to provide a means of remote indication of the progress of a variable for the operation of input tables where functions of more than one variable are being introduced. The selsyn generator can be coupled to any shaft in the analyzer, and the selsyn motor-driven counter can be mounted in any desired position.

The transportation lag device introduces functions of the form:

$$F(t) = f(t-a) \quad \text{or}$$

$$F(t) = f(t) - f(t-a)$$

These functions have been encountered in control studies where a time lag exists between the sensing of a signal and application of the signal to the control system.

The recording counter provides a record of results in the form of tabulated numerical data. Results are usually desired in the form of curves, but the recording counter may be used to extend the number of variables recorded. In some cases the recording counter has advantages over the curves because numerical results from the counter preserve a higher degree of accuracy than does a plot, and arithmetic manipulations of the output data, if necessary, are facilitated when the results are available in numerical form.

The disconnect unit is a shaft coupling which is to be used when a mechanical drive is to be engaged or disengaged frequently.

REFERENCES

1. A New Differential Analyzer, **H. A. Peterson, H. P. Knehni.** AIEE *Transactions*, volume 63, 1944, pages 221–8.

2. Analyzers, **C. Concordia, H. A. Peterson.** *General Electric Review* (Schenectady, N. Y.), September 1945, pages 29–37.

3. Differential Analyzer Applications, **F. J. Maginniss.** *General Electric Review* (Schenectady, N. Y.), May 1945, pages 54–9.

4. More Differential Analyzer Applications, **A. C. Cook, F. J. Maginniss.** *General Electric Review* (Schenectady, N. Y.), August 1949.

5. A New Type of Differential Analyzer, **V. Bush, S. H. Caldwell.** *Journal of Franklin Institute* (Philadelphia, Pa.), volume 240, October 1945, pages 255–326.

Digest of paper 50-215, "Special Devices Aid Differential Analyzer Solution of Complex Engineering Problems," recommended by the AIEE Committee on Computing Devices and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23–27, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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The Functional Design of Buildings for Electrical Education

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ALL TOO OFTEN the procedure in connection with the construction of a new electrical building on a college campus includes a point at which the architects present to the electrical engineering department a set of preliminary plans of the proposed building. This is a critical time since at this instant the electrical engineers are being given their first major opportunity to see and discuss the internal arrangements with which they are going to have to live for many years, yet at the same time the architects' ideas of exterior and general building layout have been rather definitely settled. Thereafter, any point at which the electrical engineer's ideas of interior arrangement differ from the architects' ideas of exterior arrangement may lead to a clash, often settled in favor of the architects. Unlike the doctors, the architects cannot bury their mistakes, but neither do they have to live with them!

The usual procedure should be modified and the electrical engineers should prepare and present to the architects a detailed, well-thought-out set of interior arrangements and specifications at the same time that the architects begin their work, thus placing the engineer's desires with respect to the interior on an even footing with the architect's thinking concerning exterior and general appearance. To this end we wish to present here a discussion of certain building and laboratory details, all matters which can, and should, be laid out before the architects begin their work. If this is done, the architects usually will have no difficulty in providing the desired facilities, limited only by available funds.

In order to obtain the best use of a building in which electrical engineering will be taught, many specifications for interior arrangements should be supplied to the architects before any of their plans are made. In this way, the building can be designed around its function instead of fitting the functions into the building after it is erected.

OBJECTIVES

A NEW BUILDING is an extremely permanent and expensive capital investment, but one which can give very large returns on that investment if planned with respect to the needs of the future, not those of the past. Because the dean performed his laboratory work in a certain way as a student is no reason for the students doing their work the same way, even though the dean thinks it is a good reason. The use of a building is in the future—it should be planned for the future. Since the future cannot be known, a building must be planned with logic and philosophy, not with a yardstick and a detailed list of laboratory equipment.

As a guiding philosophy in the design of buildings for engineering education a list of four freedoms is proposed:

1. Freedom from interfering influences.
2. Freedom for logical layout.
3. Freedom for flexibility.
4. Freedom from uneconomic design.

Of these the first is considered the most important, followed closely by the second. Proper planning for these two freedoms may lead to ready fulfillment of the third and fourth.

Freedom from Interfering Influences. In general, a building should provide the best possible housing for the teaching process, and the best possible arrangement of laboratory facilities to aid in that process. As a corollary to that, a building should also provide proper housing for the staff, since anything that interferes with staff morale reflects directly into the teaching process. Improvement in the efficiency of the teaching process is the main goal and an interference with the teaching process should be classified as undesirable and unwarranted. Such interference may be defined as any influence on the students' senses which does not pertain to the subject under study.

These interfering influences may include noise, visual or physical distractions, and uncomfortable environment. The passage of a pretty coed past a window can well lose a class for an appreciable amount of time. Many of these interference factors can be dealt with through building planning, and while some may be minor in themselves they become of major importance when it is realized that on a college-building basis many can only be dealt with once in 50 years! It can be said that certain of these distractions are definitely eliminated in the construction of a monastery or a prison, but later portions of this article will dispel any illusions that the type of planning proposed is along those lines.

Freedom for Logical Layout. In addition to freedom from interfering distractions, buildings and laboratories should be laid out to be logical. Questions should not have to

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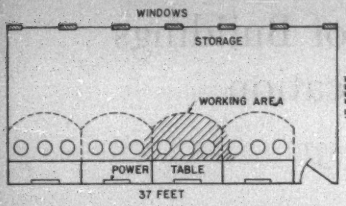

Figure 1. In this common arrangement of work tables for a 12-man section in a room 17 feet deep, the only storage space is under the windows, and the work area of one group interferes with the work area of another. Coefficient of utilization of the room is only 39.4 per cent

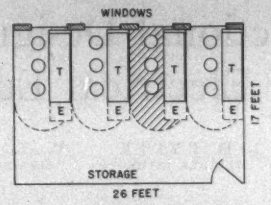

Figure 2. With this room arrangement the students have the same amount of working space; light from the windows falls on the tables; floor-to-ceiling storage is supplied, and utilization is 52.6 per cent

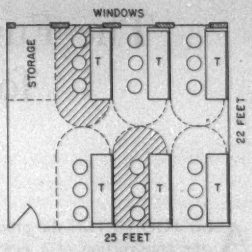

Figure 3. An 18-man room can be planned with a parallel-type layout. Utilization coefficient is 63.5 per cent

be asked, because answers should be apparent. A student should not have to ask, "Where do I go to plug 230 volts d-c onto circuit *C-37*?" The answer should be obvious in the layout of the laboratory. An instructor should not have to ask, "If this set is composed of a wound-rotor induction motor and a d-c machine, where will I find another of similar arrangement?" Again the layout should provide his answer. Student traffic to and from instrument rooms, plug panels, places of storage of minor equipment, should be studied and planned and not left to chance.

Freedom for Flexibility. By this is meant freedom to rearrange functions, in effect to redesign the building if a future need arises. It may be possible to predict the space needs of various instructional and research fields quite accurately as of today, but who can say what instructional and research areas will be in existence 20 years from now, without even attempting to predict their space needs. Modular exterior and readily removable room partitions provide the answer, giving a flexibility of internal arrangement in terms of some small modular distance. The strip windows so common now also lend themselves to this and prevent the architect from first laying out a window arrangement to which all interior planning must subsequently conform, an old architectural habit. The height of these windows may be made to eliminate at least a portion of the external distractions seen from a classroom. This is definitely an aid in retaining student interest in the teacher's remarks when the classroom faces a busy city street, or when spring calls a young man's fancy.

Freedom from Uneconomic Design. To the Board of Trustees an uneconomic design is almost always one which has a high price tag, when it is known by all that the reverse may be true. Such Boards will not concern themselves with cost details and would be inexpert if they did. Since they will not consider these design details, it follows that the engineers must, and it is to our interest to do so since thereby we may obtain more usable space for the allotted funds.

Building costs are frequently figured on a cost per square foot or per cubic foot basis. Any planning which can reduce the square feet thereby reduces cost and is desirable if it does not interfere with the building function—that of teaching. As will be shown in the following portion of this article, square feet can frequently be reduced with a concurrent improvement in teaching conditions. To this end certain room arrangements will be considered.

BUILDING PLANNING

A FEATURE which is paramount in cost is the depth of rooms, measured from the hallway. A first tendency is to center the hallways, leading to a common depth for all rooms. A better arrangement may be to throw the hallways off center, giving rooms of two different depths, one suited to office use, the other of greater depth designed for classroom or laboratory.

In order to consider the planning of laboratory space from a general viewpoint, it is necessary to depart from the general and make certain specific assumptions to illustrate the general method. Arbitrarily, it may be assumed that the depth of laboratory space will be established near to either of two values, 17 feet or 22 feet. These seem to lie near values frequently selected for rooms in modern buildings, and are at least suitable, as will be shown. They also avoid excessively deep dimensions which lead to high cost, and, as will be shown later, are economical in floor area, both matters being of extreme interest to the Board of Trustees.

Small Laboratory Arrangement. Having selected several suitable depths, the next matter to be determined is length, which is definitely tied in with internal function and arrangement. Taking first the matter of laboratories for small apparatus, circuits laboratories, electronics laboratories, radio laboratories, and the like, many schools prefer, although are not always able to maintain, a small section size, say of 10 to 12 men. It may be mentioned here that laboratories which are planned for this size section, and are not oversize, are powerful arguments against any administration move to increase section sizes arbitrarily. Taking a 12-man section as standard, subdivided into four 3-man groups, a very common arrangement of work tables is that of Figure 1, in the room of 17-foot depth.

If used as shown, only space under the windows is available for equipment storage. If, to increase storage space, the tables are placed along the windows, then the very bad situation arises of having students facing bright outdoor light for long periods. This is also an argument

against doubling the room occupancy by placing tables along both walls. Working tables in the center of floor areas lead to traffic troubles and a confused appearance in the room, as well as complicating electrical service to these tables, due to future inflexibility of buried conduits in floors.

Using indicated working and interference areas as shown in the figure, a coefficient of utilization may be defined as the ratio of the area utilized in actual student work to the total floor area. For this room this figure is 39.4 per cent, not too pleasing to a statistically minded Board of Trustees. In addition, the indefinite work area of each group and the time taken for intergroup student gossip both introduce distractions and reduce student working efficiency.

The arrangement of Figure 2 seems more desirable. Student working areas in square feet are as before, but interference areas and interference are greatly reduced. The working areas of each group are definitely defined; it is not easy to gossip with the next group, and good working efficiency is obtained. A corollary advantage is that when an instructor wishes to check equipment operation he need not elbow into a working group, but goes to the back of the table and talks across the table with the particular students concerned, or checks their circuit connections.

This layout also permits the tables to be placed on the window side, gives full wall space for equipment storage, and needs no extra room length for a doorway. The area is only 442 square feet compared to 620 square feet of Figure 1, and the coefficient of utilization is 52.6 per cent.

Figure 3 illustrates the layout of Figure 2, expanded to handle an 18-man section in a laboratory of the 22-foot width. An instrument or storage room also is included. Where section sizes must be large, or room sizes suited, this layout is efficient although not so desirable as Figure 2. The area is 550 square feet and the coefficient of utilization is up to 63.5 per cent.

Table I summarizes the characteristics of these three basic plans.

Table I. Characteristics of Basic Plans

	Plan 1	Plan 2	Plan 3
Size of laboratory, square feet	620	442	550
Students handled	12	12	18
Cost at $18 per square foot	$11,160	$7,956	$9,900
Cost per student	$930	$663	$550
Coefficient of utilization	0.394	0.526	0.635

An example of the parallel-table layout is shown in Figure 4.

Instrument Rooms. It is highly desirable to combine such laboratories in pairs, related by common use of similar equipment, with an instrument room placed between, as in Figure 5. This permits lock and key storage of the more valuable equipment items, reduces distance and travel time to a more remote instrument room, and is more efficient in usage of floor area than separate rooms for each laboratory.

Power Distribution. A system of bus ducts or some other relatively high-current-capacity distribution system should make power available at a convenient point in the small laboratory. At that point a main distribution panel should be provided with protective equipment and circuits emanating from it suitable to the power requirements of the particular laboratory.

Certain known fixed-voltage circuits are normally supplied. In addition, transfer, or variable-use circuits, are useful for supplying the unpredictable or nonstandard needs of laboratories.

Power Outlets. The ultimate terminal of the power distribution system within the laboratory is the power outlet panel and associated equipment at the student work bench.

The single normally positioned work bench plan lends itself admirably to a simple panel board plan, as, for example, a circuits laboratory. The panel boards are located at the left end of the work bench. In addition to the laboratory circuits terminating on the panel board, a 115-volt a-c plug strip is provided along the length of each bench for supply to vacuum-tube voltmeters and other test equipment of similar nature. The student's power switch operates a red and a green pilot lamp giving a visual indication of whether his switch is closed or open.

Large Laboratories. In the design of large laboratories such as machinery laboratories the basic requirements of logical arrangement and freedom from interference also can be met. A much-used laboratory table and machine arrangement is shown in Figure 6, the table usually being on wheels. The problem posed to the student here is: "I must work in the space between machines and table to make my connections, yet as I make my connections I cannot work in the space!"

An answer to this problem is available by turning the

Figure 4 (left). The working area for each group is clearly defined by this placement of laboratory tables. The tables are well lighted, and the student does not have to face the bright outdoor light for long periods

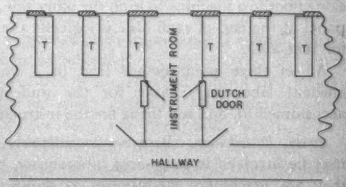

Figure 5 (above). For maximum utilization of equipment and space, laboratories are combined in pairs with an instrument room between them

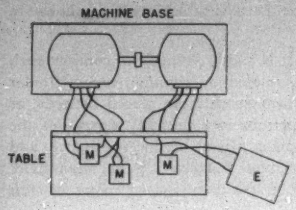

Figure 6. This widely used arrangement of laboratory table and machine makes it virtually impossible for the student to get to his space between the machines and the work table

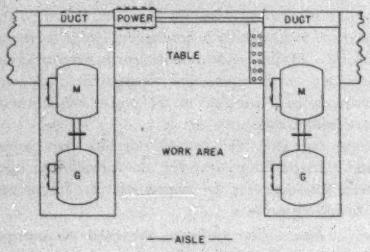

Figure 7. With the work table perpendicular to the machines, the danger and inconvenience of dangling leads are eliminated

table at 90 degrees to the machines, as shown in Figure 7. In addition the cubbyhole, or defined working area, advantages of the previous small laboratory layout also are obtained. Power feeds from one side, across the table through the instruments, to motor and generator by way of transfer plugs, which also furnish potential points. These transfer plugs prevent long leads from pulling instruments off the table. This arrangement is shown in Figure 8.

By arranging these working areas side by side, in aisles, and supplying power to each aisle, the whole laboratory appears as in Figure 9. As many sets per aisle as desired may be used, and as many aisles placed side by side as space permits. By arranging machines of similar design in each aisle, these sections usually will work in one aisle at a time, saving shoe leather of the instructor.

Space in the cubbyhole and to some extent in the aisle is available for loads, inductors, and other large portable pieces of equipment. The equipment in two aisles is staggered, see Figure 9, allowing the use of common power panels for two groups, and placing a working area on one side opposite a machine base on the other side. The power panel at the end of each aisle is logically the power panel for that aisle.

All of these small details lead to a smooth-working efficient laboratory, easier for the student to become accustomed to, and less tiring for the instructor.

Power Distribution. Because considerably more power may be involved in large-area laboratories, particularly if they are machinery laboratories as shown in Figure 9, several distribution panels are desirable. These panels should be arranged logically with respect to the areas they serve to avoid confusion. Figure 9 illustrates a subline plan in which the distribution panel board serves a total of eight student work areas.

Fixed voltage circuits are supplied through suitable protective equipment on the main distributing panel. Transfer circuits also are provided here, as on and between all panel boards for circuit distribution.

Power Outlets. The student work area in a power machinery laboratory is shown in Figure 8. The power panel board is shown on the left of the work area. The instrument bench should be approximately two feet wide by six feet long. The space at the right of the power panel is an instrument connection and control panel. This is segregated into modular sections that can be adapted to the needs of the particular machine set and experiment. The modular sections may be semipermanently installed, but easily adaptable to changing needs as new experiments may require.

The machine set associated with the student work area here appears on the base at the right of the work area. Plug and jack arrangements should be completed at the left of the control panel and at each end of the work-bench frame. Loading resistors, inductors, or capacitors should be connected at the left-end panel of this work-bench frame.

Supplementary large capacity switches, rheostats, and so forth may be located between the two end panels of the work-bench frame.

Instrument Rooms. The location of large-area laboratories with respect to student traffic should be considered carefully. Rooms may be designed so that two service pass doors permit issuance of instruments at one window and reception at the other. This is desirable particularly where one laboratory period begins and another ends at the same time.

PSYCHOPHYSIOLOGICAL ASPECTS

HUMAN BEINGS react to many stimuli, as do all living organisms. Often the human does not react because he consciously wills to do so but because the very nature of the human body is so developed as to cause him to react independently of his own will. In addition to purely psychological reactions, the same stimuli often produce physiological reactions. By controlling the environment these psychological and physiological reactions can be made to contribute to the well-being and productivity of the individual rather than to detract or to yield only neutral results.

Some of the aspects of building design that fall within these categories are discussed now.

Color. Human beings are drawn to light, and one of the important aspects of light is color. Color can be chosen and controlled by the architect to yield pleasing appearance and also to perform functional results simultaneously. Neutral or receding colors such as soft gray or pastel greens and blues should be used for large area expanses. Warm colors and vivid hues, particularly in the reds, yellows, and oranges, may be used in smaller areas to provide contrast, life, and direction of attention, as in stairwells.

Appearance Factors. Architects tell us that the high window height previously mentioned also produces a better balanced exterior because the exterior space from ground to first window is better balanced with respect to the space from top window to parapet.

Colored chalkboards blend well with other room decoration in color and tend to become a part of the room rather than something apart as did the grayed, gloomy blackboard. Contrast from white chalk to the green board is not radically different from that to a chalk-impregnated blackboard. The psychology of color enters a great deal into the feelings of the observer.

Most buildings require structural columns at 17- to 22-foot intervals. These columns should be located inside the corridor walls, thus giving a pleasing appearance to the public areas of the building as in a corridor.

Drinking fountains and fire extinguishers should be set flush with the corridor wall. The smooth appearance thus achieved is not only pleasing to the eye but functional as well, because traffic flow is not impeded by obstructions.

Lighting. Modern lighting design strives to achieve a good visual environment. Such design must recognize the following basic facts: (1) excessive brightness of lighting sources and contrast with the surroundings produce glare and a poor visual environment, (2) size and position of the source are important elements in evaluating lighting systems, and (3) the more prolonged and difficult the seeing task, the better should be the visual environment.

Corridor lighting can employ the bare-lamp technique inasmuch as the seeing task is rather elementary and casual and does not require a very high quality of visual environment in so far as brightness patterns are concerned. It is possible to employ slimline continuous tube lighting for corridor applications.

The seeing tasks in classrooms and offices are prolonged and difficult and consequently require close control of the source brightness from the normal angles of view. Fluorescent 2-lamp units may be suspended slightly from the ceiling to yield more uniform ceiling brightness and thus improve the visual environment.

Separate switch control on luminaires on the window side of the room permit operation of the inner lamps for boosting the illumination there. On dark days all lights are needed, on some days only the inner lights are necessary, and on bright days with sunshine no artificial lights may be needed.

Office and small-laboratory lighting follow the same pattern as classroom lighting, especially if the full use of modular window design is to be utilized as the building undergoes changes in room arrangements with a lapse of time. The lighting, if adapted to the same modular dimensions as the windows, permits cross wall changes with a minimum of circuit changes and absolutely no luminaire changes. A new room arrangement at the most may require a new switch circuit.

Laboratories that utilize instruments having mirror reflectors for checking the elimination of parallax require a very uniform ceiling pattern of brightness when viewed straight upward. Indirect luminaires or luminous ceiling

Figure 8. With this setup power leads can be connected to the instruments and from them to the motor and generator through transfer plugs

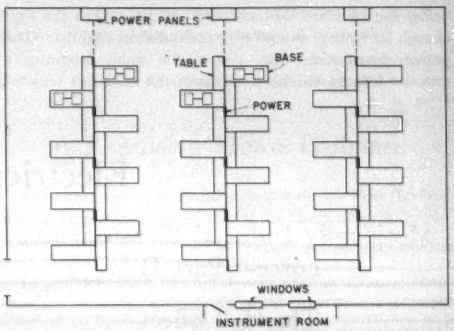

Figure 9. Diagram of a power laboratory arranged for the convenience of both the instructor and the student

systems are required for this application so that the ceiling brightness can be made very uniform.

A system employing indirect silver-bowl lamps and concentric ring louvers for shielding the brightness of the neck of the lamp may be used. This type of indirect system assures good maintenance; first, because very little area is exposed for collection of dust, and second, because with each lamp replacement a new indirect reflector system is installed.

Design of buildings for natural lighting is economical and very desirable in areas of the nation possessing abundance of clear weather. Even in the Midwest, natural lighting can be utilized to excellent advantage. Control of window brightness is a subject of great importance if a good visual environment is to be achieved.

Prismatic glass block is a method of control that yields excellent results for south exposure. A laboratory approximately 70 feet deep has been built which, with prismatic glass block on the south and very high sky exposure windows on the north, obtains at least 50 footcandles at any location on a clear day. Furthermore, a very uniform ceiling brightness results because of the light directed upward across the room by the glass blocks.

Venetian blinds of both conventional horizontal slats

and special louver styles of both the exterior horizontal type and the interior vertical type may be employed for rooms where the occupant's direction of view is established.

Heating and Ventilation. A heating and ventilation system employing a hot-water base-load type controlled by exterior thermostats and supplemented by a circulating air system with final temperature control by interior thermostats is capable of providing excellent temperature control as well as comfortable air circulation. The system is also capable of air conditioning through the air component system.

The radiators of the water-component system should be installed fairly low on the outside walls to provide radiation slightly less than the heat loss of the building. The radiators consist of fins attached to a pair of circulating water pipes. These radiators may be located conveniently just below the standard 30-inch table height so that the tops of such tables may extend over the radiators slightly. The power distribution duct system for small laboratories may be located on the wall above the radiators without being exposed to excessive temperature because the water temperature is not extremely high even for unusually cold winter days.

Furred ceilings in the corridors may be used to good advantage for the air ventilating system as well as other building services such as power distribution bus ducts and so forth. The forced air may be carried in air ducts with vents into the rooms on a modular dimension equal to twice the window modular dimension. Return air is carried in the open furred space with vents from the rooms in the alternate modular spaces as well as with vents in the ceiling of the corridor to pick up cool air from that location.

CONCLUSIONS

When building planning is begun well in advance of the architect's drawings, fine co-operation between the architect and the user can be achieved. The results are buildings that are highly functional, reasonable in cost, and beautiful to the eye.

Electrical Essays

Motionally Induced Electromotive Force—Part II

The Hall Effect

Jack, the physicist, is continuing his lecture to Alter Ego and his friends explaining the principles of electric motors and generators (see Part I, *EE, Nov '50, pp 1025–26*).

Jack: "As I was saying before Alter Ego interrupted me, the electrons in the cross bar of Figure 1 have to move with its velocity **v** in the direction perpendicular to the magnetic field, and therefore will have acting on them on this account a force

$$\mathbf{F}=e\frac{1}{c}[\mathbf{vxB}] \tag{1}$$

"Since this force is proportional to the charge e, it produces the same effect as if there were an electric field acting on it:

$$\mathbf{E}_{mot}=\frac{1}{c}[\mathbf{vxB}] \tag{2}$$

"We'll call $\mathbf{E}_{mot}$ of equation 2 the motional field, or motionally induced electric field. If we integrate it from one point to another, we'll call the result the motionally induced electromotive force, although if **v** is not constant throughout the material, this integral may depend on the path of integration.

"In a moving metal, then, since not only the regular electric field **E** but also $\mathbf{E}_{mot}$ will be acting on the electrons, the current density will not be given by Ohm's law

$$\mathbf{i}=\sigma\mathbf{E} \tag{3}$$

where σ is the conductivity of the metal, but we will have instead

$$\mathbf{i}=\sigma\left(\mathbf{E}+\frac{1}{c}[\mathbf{vxB}]\right)=\sigma(\mathbf{E}+\mathbf{E}_{mot}) \tag{4}$$

"If we make the current zero, as by opening the circuit of Figure 1, then we must have $\mathbf{E}+\mathbf{E}_{mot}=0$, and $\mathbf{E}=-\mathbf{E}_{mot}=-\frac{1}{c}[\mathbf{vxB}]$. To get the open circuit voltage then, since $\mathbf{E}=-$gradient V where V is the electrostatic potential, we integrate through the wires of Figure 1 from the one open end to the other, and get

$$V_o=\int -\mathbf{E}\cdot\mathbf{ds}=\frac{1}{c}vBl \tag{5}$$

where l is the length of the slide wire between the two sliding contact points.

"If I close the circuit, the total current I will be given by

$$RI=V-V_o=V-\frac{1}{c}vBl \tag{6}$$

where R is the resistance of the circuit.

"Multiplying equation 6 by I, we get

$$VI=RI^2+V_oI=RI^2+\frac{1}{c}vIBl \tag{7}$$

where VI is the electrical power input, RI^2 is the Joulean heat developed, and $V_oI=\frac{1}{c}vIBl$ is the mechanical power, since $\frac{1}{c}IB$ is the force which acts per unit length on a conductor carrying a current I, and which lies in a perpendicular magnetic field **B**. But I see that Alter Ego

has been trying to ask a question. What is it, Alter Ego?"

Alter Ego: "This **v** in your equations is the velocity of the electrons in the magnetic field, which you produced by moving the slide bar, but there are other ways of giving electrons velocity. For example, in a piece of metal, at rest, if I send current in it, I'll have

$$\mathbf{i} = ne\mathbf{v} \text{ or } \mathbf{v} = \mathbf{i}/ne \tag{8}$$

where n is the density of electrons in the metal.

"Now, if I put this metal carrying current in a magnetic field, even though the metal is at rest, the electrons are moving, and I'll get a motional field

$$\mathbf{E}_{mot} = \frac{1}{c}[\mathbf{vxB}] = \frac{1}{cne}[\mathbf{ixB}] \tag{9}$$

Is that right?"

Jack: "Well, we do not usually call it a motional field, but what you have done is to independently discover the Hall Effect. Not only that but you have even given a formula for the Hall Effect coefficient, $1/cne$, which is just about right. That is wonderful, Alter Ego!"

Alter Ego: "I don't know how big n is, but at least I know it is positive, and c is positive, and e is negative, so I can be very sure that the Hall Effect coefficient is always negative, isn't that right, Dr. Jack?"

Jack: "Well no, some metals, zinc, cadmium, and lead, for example, have Hall Effect coefficients of the opposite sign."

Alter Ego: "Gosh! Then the electrons in these metals have a positive charge?"

Jack: "No. You see, the electrons in the metal are not quite as simple as I made out. They are really wave functions in the periodic lattice potential and because they are degenerate, they satisfy Fermi-Dirac statistics, and lie in the bottom portion of a band of allowed energy levels. Some of the electrons get pushed into the upper energy levels and leave holes in the assembly of electrons in the lower levels, and these holes act like electrons with positive charge."

Alter Ego: "Double gosh! Then you can have a force like $\frac{1}{c}[\mathbf{vxB}]$ acting on a hole?"

Jack, weakly: "Yes."

Alter Ego: "Well, anyway, since you told me the Lorentz force formula is all right, I can be sure that the Hall Effect is proportional to **B**, isn't that right?"

Jack: "Well, no. The Hall Effect in the magnetic metals is not proportional to either **B** or **H**. The Hall Effect is quite complicated in these metals."

Alter Ego: "Then, when calculating the motional electromotive force of a conductor moving in a magnetic field, like in the slide-wire experiment, you say that the electrons are small bodies with charge e, moving in the Maxwell field **B**, subject to the Lorentz force, $\mathbf{F} = e\frac{1}{c}[\mathbf{vxB}]$, thus giving the motionally induced electric field $\mathbf{E}_{mot} = \frac{1}{c}[\mathbf{vxB}]$, which is the same for all metals; but when I move the electrons in the stationary metal to calculate the Alter Ego Effect, also known as the Hall Effect, then you say the electrons become waves, or holes, their charge is no longer the negative number e, they no longer move in Maxwell's **B** or even **H**, so they certainly can't have acting on them the Lorentz force, $e\frac{1}{c}[\mathbf{vxB}]$. I am confused."

Jack: "I am a bit confused, too. I knew that the simplified electron theory I gave you was wrong, but at least you would understand it. Instead I should have given you the true theory, which you could not possibly understand."

(To be continued.)

There are several questions to be asked: 1. Should Jack have appealed to electron theory at all? 2. Did Jack present the simple Lorentz picture correctly? 3. Is there not some more general macroscopic principle or theory that Jack might have appealed to rather than the electron theory of the microstructure of matter?

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A Repulsion Motor Problem

The operation of a repulsion motor depends on the fact that a copper ring moves out of an alternating magnetic field or turns until the plane of the ring is parallel to the lines of force (Thomson's experiment).

In practice, the switching devices of these motors (commutator, brushes, wound armature and its attendance)

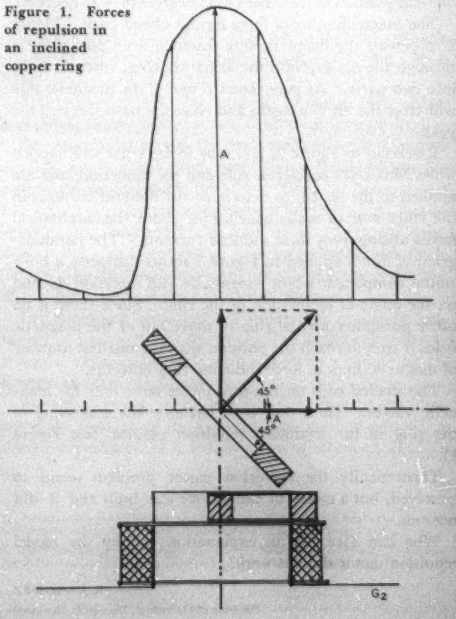

Figure 1. Forces of repulsion in an inclined copper ring

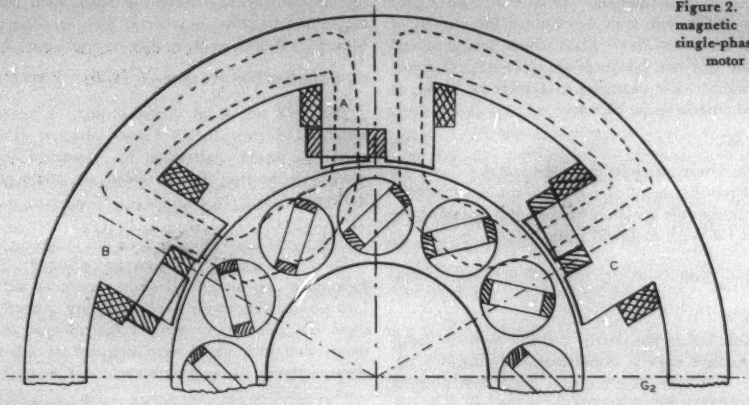

Figure 2. Path of the magnetic flux in a single-phase repulsion motor design

often are sources of trouble. To overcome these insufficiencies and to spare materials for construction, I tried to design an armature system that meets all requirements of a repulsion motor but lacks the ordinary-type armature parts.

A copper ring that is inclined 45 degrees to its direction of motion will not get its maximum repulsion directly above the field magnets but displaced sideways from them. Figure 1 shows the force distribution as a function of the ring position. A lever device is provided to select the direction of torque by turning the plane of the ring from one end position to the other (+45 degrees to −45 degrees).

The magnetic lines of force form a closed path. Figure 2 represents the magnetic flux reaching from pole piece *A* through the air gap into the armature core, where it splits into two parts. At pole pieces *B* and *C* the magnetic flux will cross the air gap again and close the path through the yoke.

Referring to Figure 2, it is easy to see what will happen when Maxwell's corkscrew rule and the induction laws are applied to the system to determine the induced currents in the rings and to make conclusions about the mechanical forces arising from these induced currents. The parallelogram of forces applied in Figure 1 shows distinctly a horizontal component whose magnitude and direction depend on the angle of inclination of the ring. Since there is no other possibility for the ring to move out of the magnetic field, it tries to reach the position with the smallest number of magnetic lines of force inducing ring currents.

The shaded coils on the pole pieces serve only for magnetic valves. Their task is to facilitate the traversing of the ring in its maximum repulsion position (see Figure 1).

Theoretically the repulsion motor problem seems to be solved, but a model of the device was built and it did not run.

Who can give me an explanation of why the model repulsion motor did not work?

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Answers to Previous Essays

Motionally Induced Electromotive Force—Part I. The following is the author's answer to his previously published essay (*EE, Nov '50, pp 1025–26*).

No, I do not think Jack answered Alter Ego's question properly. Alter Ego also made some incorrect statements in his question.

Let us settle Alter Ego first. Alter Ego said that in a small lozenge-shaped hole in a body, the component of the electric field $\boldsymbol{E}_n^*$ in the hole normal to the lozenge-faces is $\mathbf{D}_n$ and the component parallel to the faces, $\boldsymbol{E}_s^*$, is equal to $\mathbf{E}_s$ where $\mathbf{E}$ and $\mathbf{D}$ are the two Maxwellian electric fields in the body. He also asserted similarly that $\boldsymbol{H}_n^* = \mathbf{B}_n$ and $\boldsymbol{H}_s^* = \mathbf{H}_s$. These statements are true for a body at rest, but not for a body in motion (*EE, Nov '50, pp 1025–26*).

For a body in motion, we continue to have as defining $\mathbf{H}$ and $\mathbf{B}$

$$\mathbf{D}_n = \boldsymbol{E}_n^* \tag{1}$$

$$\mathbf{B}_n = \boldsymbol{H}_n^* \tag{2}$$

These two equations ensure that Maxwell's equations concerning div $\mathbf{D}$ and div $\mathbf{B}$ will hold in all empty space, even in empty space crevices in stationary or moving bodies.

For moving bodies, however, to define $\mathbf{E}$ and $\mathbf{H}$ we have

$$\mathbf{E}_s + \frac{1}{c}[\mathbf{v} \times \mathbf{B}]_s = \boldsymbol{E}_s^* + \frac{1}{c}[\mathbf{v} \times \boldsymbol{H}^*]_s \tag{3}$$

$$\mathbf{H}_s - \frac{1}{c}[\mathbf{v} \times \mathbf{D}]_s = \boldsymbol{H}_s^* - \frac{1}{c}[\mathbf{v} \times \boldsymbol{E}^*]_s \tag{4}$$

These equations ensure that Maxwell's equations concerning curl $\mathbf{E}$ and curl $\mathbf{H}$ will hold in all empty space, including crevices in matter moving with velocity $\mathbf{v}$. (See, for example, reference 1, and later essays in which I hope to develop this subject.) Equations 3 and 4 serve to define $\mathbf{E}$ and $\mathbf{H}$ within the moving matter.

Applying these relations to Alter Ego's lozenge shaped

holes, we have for his three orientations, assuming **B** is parallel to **H**, and **D** is parallel to **E**:

Faces perpendicular to magnetic field

$$\boldsymbol{E}^* = \mathbf{E},\ \boldsymbol{H}^* = \mathbf{B}, \text{ and } \mathbf{F} = \epsilon\left(\mathbf{E} + \frac{1}{c}[\mathbf{v}\mathbf{x}\mathbf{B}]\right) \tag{5}$$

Faces perpendicular to electric field

$$\boldsymbol{E}^* = \mathbf{D},\ \boldsymbol{H}^* = \mathbf{H}, \text{ and } \mathbf{F} = \epsilon\left(\mathbf{D} + \frac{1}{c}[\mathbf{v}\mathbf{x}\mathbf{H}]\right) \tag{6}$$

Faces perpendicular to velocity

$$\boldsymbol{E}^* = \frac{1}{1 - v^2/c^2}\left(\mathbf{E} + \frac{v}{c}[\mathbf{B} - \mathbf{H}] - \frac{v^2}{c^2}\mathbf{D}\right)$$

$$\boldsymbol{H}^* = \frac{1}{1 - v^2/c^2}\left(\mathbf{H} + \frac{v}{c}[\mathbf{D} - \mathbf{E}] - \frac{v^2}{c^2}\mathbf{B}\right)$$

$$\mathbf{F} = \epsilon\left(\mathbf{E} + \frac{1}{c}[\mathbf{v}\mathbf{x}\mathbf{B}]\right) \tag{7}$$

so that Alter Ego's equation 5 was wrong.

Now turning to Jack, the physicist, I must first criticize him for referring to electron theory at all, in developing electromagnetism in moving matter as applied to the electric motor. Electric motors were running before the electron was discovered, and they have continued to run quite undisturbed as the electron changed from the charged ordinary Newtonian particle of J. J. Thomson and Lorentz to the quantum-mechanical complex probability-density wave-function, with Fermi-Dirac statistics, and negative energy states, of today. We should have and do have an electromagnetism of macroscopic bodies, with concepts defined by operations on macroscopic bodies, and sufficient for the electric motor, and independent of the current theory of the electron and the microphysics of matter.

If we know the electric and magnetic fields in empty space adjacent to bodies and in crevices in bodies, and if Maxwell's equations hold in this empty space, then equations 1, 2, 3, and 4 will define vectors **D**, **B**, **E**, and **H** at points inside matter, and Maxwell's equations will hold for these vectors with ρ defined by $4\pi\rho = \text{div } \mathbf{D}$, and with defined by $\frac{4\pi}{c}\left(\mathbf{i} + \frac{1}{4\pi}\frac{\partial \mathbf{D}}{\partial t}\right) = \text{curl } \mathbf{H}$.

We then look for constitutive relations between these field quantities which depend only on the nature of the material involved, but now, along with pressure, temperature, and so forth, which are parameters defining the nature of the material, we must include the velocity **v**. Thus we may find that experiment verifies the relation

$$\mathbf{i} = \sigma\left(\mathbf{E} + \frac{1}{c}[\mathbf{v}\mathbf{x}\mathbf{B}]\right) \tag{8}$$

for metals for which at rest, $\mathbf{i} = \sigma\mathbf{E}$. Then equation 8 is a constitutive equation for such metals in motion. But enough of this for now. There will be more another time.

Let us consider Jack the physicist's argument based on the Lorentz theory of the electrical structure of matter. Let us accept Lorentz's postulate that matter is made of charged particles, electrons and ions, which behave like charged macroscopic small bodies, having definite position in space and time, producing electric and magnetic fields, and being acted upon by nonelectrical or mechanical forces as well as the forces of the electric and magnetic field, even though it is now well known that the individual electrons and ions do not behave at all like macroscopic small charged bodies.

Then under these conditions, Lorentz showed that for a medium, at rest, the average of the microscopic electric fields over an extended region would be the Maxwell field **E**, and the average of the microscopic magnetic fields would be Maxwell's **B**. But is this true also for a medium in motion? The moving electrons and ions will produce different microscopic fields than when they are at rest, and it is not at all clear these fields will continue to average to Maxwell's **E** and **B**.

More serious than this, however, is the question as to whether the electron is to be regarded as in the average fields **E** and **B**. The electrons are not scattered through the metal completely at random. They will tend to favor some interatomic regions and avoid others. Thus the average field that an electron finds itself in is not the same as the average field throughout a whole region, and therefore the electron cannot be said to be in either Maxwell's **E** field or Maxwell's **B** field.

The reasoning of Jack, the physicist, was not sound. Alter Ego's question, "What is the shape of the holes the electrons move in?" has not been answered.

REFERENCE

1. Electrodynamik, **Sommerfeld.** Dieterichsche Verlagsbuchhandlung, 1948, page 288.

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Switching Gravity On and Off. The following is the author's answer to his previously published essay (*EE, Nov '50, p 1026*).

The scientist was the famous physicist, Dr. Max Steenbeck, of the Siemens Schuckert Company, in Berlin.

Dr. Steenbeck placed the arc, together with a movie camera, inside a box, and, with proper flexible leads for power and oscillographic recording, tossed the box upward to a height of about ten feet, letting it fall freely back again. With respect to co-ordinate axes moving with the box, during the free flight, there was no gravitational field. Thus within the box, gravity was turned off at the beginning of the flight, and turned on again at the end.

Dr. Steenbeck describes the interesting results he obtained in a paper.[1] In this paper, Dr. Steenbeck refers to a similar experiment made with respect to a candle by H. Lorenz of Bonn, Germany.

Professor Lorenz, in his paper,[2] states that he saw Professor W. Gerlach of the University of Munich perform a similar experiment in a lecture demonstration in 1932.

REFERENCES

1. Investigation of Electric Arc in Gravity-Free Space, **Max Steenbeck.** *Physikalische Zeitschrift* (Leipzig, Germany), volume 38, 1937, pages 1019–21.

2. Demonstration of "Inertia Force" on a Freely Falling Candle Flame, **H. Lorenz.** *Physikalische Zeitschrift* (Leipzig, Germany), volume 35, 1934, page 529.

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Stability of Voltage Regulators

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THE PRESENCE in many voltage regulator circuits of nonlinear control elements has prevented a complete mathematical treatment of the subject. However, Liapounoff's theory[1] of the stability of dynamic systems affords a solution to the problem of stability of electric circuits subjected to small displacements from equilibrium.

Liapounoff has shown that stability of the continuous periodic solutions of a set of nonlinear differential equations is determined by the stability of its linear perturbation equations. For example, let $f(I_1, V)$ indicate the nonlinear voltage developed across the generalized control element C

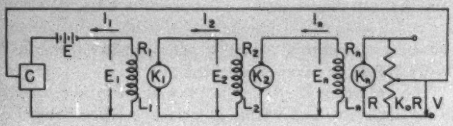

Figure 1. Voltage regulated n-stage d-c generator

in the n-stage d-c generator of Figure 1. The characteristic equation of the set of perturbation equations of the system is

$$\left(p+\frac{R_n}{L_n}\right)\left(p+\frac{R_{n-1}}{L_{n-1}}\right)\cdots\left(p+\frac{R_3}{L_2}\right)\left[p+\frac{R_1}{L_1}\left(1+\frac{f_{I1}}{R_1}\right)\right]+ K\frac{R_1R_2\cdots R_n}{L_1L_2\cdots L_n}f_V=0$$

in which f_{I1} and f_V are the partial derivatives of the control voltage function, evaluated at the equilibrium point, and $K=K_0K_1\cdots K_n$ is the open-loop gain of the complete circuit. Stability of the voltage regulator is decided by the roots of the characteristic equation.

A common type of control element is the step resistor, the resistance value of which is varied in steps by the generator output voltage. The essential features of its stability in connection with Figure 1 may be observed by assuming that the resistance varies linearly and continuously with control voltage when the latter exceeds a critical value V_c; that is,

$R_c=0$ if $V<V_c$

$R_c=K_c(R_1/V_c)(V-V_c)$ if $V>V_c$

The dimensionless constant K_c, the slope of the control-resistance–control-voltage characteristic when the former is measured in units of R_1 and the latter in units of V_c, plays an important role in the stability of the ciruit. In fact, by means of the Routh-Hurwitz stability criterion,[2] it is readily shown that, for $n=3$, if $K_c<1$, the system is always stable regardless of gain, whereas if $K_c>1$, the stability boundary is given by the expression

$$\left[\frac{1}{2}(\sqrt{1+\alpha_1}-1)+\alpha_2+\alpha_3\right]\left[1+\frac{1}{2}(\sqrt{1+\alpha_1}-1)\left(\frac{1}{\alpha_2}+\frac{1}{\alpha_3}\right)\right]=\sqrt{1+\alpha_1}$$

where

$$\alpha_1=4\frac{K_c}{(K_c-1)^2}K_0K_1\cdots K_n\frac{E}{V_c}$$

$$\alpha_2=\frac{1}{K_c-1}\frac{R_3L_1}{L_2R_1}$$

$$\alpha_3=\frac{1}{K_c-1}\frac{L_1}{L_3R_1}$$

This boundary is a surface shown in contour form in Figure 2. The region of instability lies inside the mound enclosed

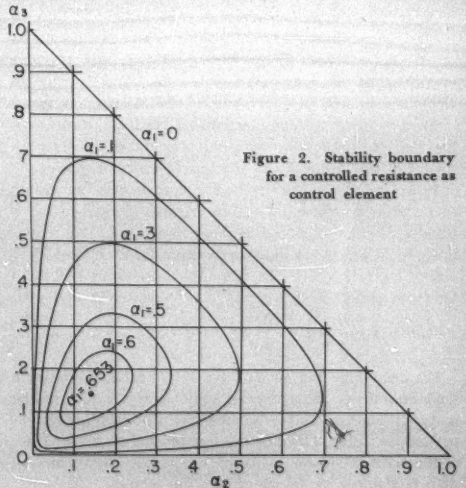

Figure 2. Stability boundary for a controlled resistance as control element

by the surface and the co-ordinate plane $\alpha_1=0$. Stability may be insured by raising the total gain K. For the stability boundaries of the linear control element and of the nonlinear controlled resistance element, the variable α_1 is in each case proportional to the circuit loop gain.

Digest of paper 50-231, "Stability of Voltage Regulators," recommended by the AIEE Committee on Feedback Control Systems and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23–27, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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REFERENCES

1. The General Problem of Stability of Motion (book), M. A. Liapounoff. Princeton University Press, Princeton, N. J., 1947, 474 pages.

2. The Conditions for which an Equation Possesses only Roots with Negative Real Parts (in German), A. Hurwitz. *Mathematische Annalen* (Berlin, Germany), volume 46, 1895, pages 272–84.

Terminal Risers for Impregnated Paper Cables

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FELLOW AIEE

CONSIDERABLE DIFFERENCES of opinion and corresponding differences in practice exist about the safe height for vertical terminations of solid-type paper-insulated cables. The limitations are vacuum formation at the top of well-sealed risers, leads stretching at their base, and moisture effects if the potheads are not hermetically sealed.

The problem is to maintain intact a group of parallel capillary columns of viscous oil. These columns lie in the interstitial edge spaces of paper and metallic tapes, interstrand spaces of conductors, spaces in the fillers, flat spaces between tapes, and between the fibers of paper.

The information at the disposal of the Committee making this investigation was vague and contradictory, and a schedule of at least 17 items was required to define a riser installation properly. Practically none of the data available was so specified.

The principal forces at play in an unloaded or lightly loaded cable are the weight of the oil column and the hoop stress in the lead which opposes it. The hoop stress is proportional to the difference between the compressive stress due to the atmosphere and the tension due to the oil column. These are equal when the oil column is about 35 feet high, and for greater heights the hoop stress is a tension corresponding to the excess of the height over 35 feet. As a normal sheath of copper-bearing lead is able to carry a hoop stress corresponding to an internal gauge pressure of about one atmosphere, such a sheath, under ideal conditions, should be able to support a riser of 70 feet, and there are cases where this has been done.

Experience has shown that absolute gas tightness of potheads cannot be relied upon, especially in installations involving a large number of potheads on pole risers, and it is, therefore, customary to assume the possibility of slow leaks and to design accordingly. On this basis, the critical height of a riser equals $5PT/D$. In a relationship such as this, P is the permissible hoop stress, usually taken as 125 pounds per square inch for plain lead, 150 pounds per square inch for copper-bearing lead, and 175 pounds per square inch for arsenic-alloy lead; T is the thickness of sheath in inches; and D is the internal diameter of sheath in inches.

A loaded cable has transient expansion pressure superimposed on the slow build-up of gravity head pressure, and if the total pressure exceeds the creep strength of the sheath, stretching will occur and will be cumulative unless this condition is relieved.

For heights above the critical, or where loading adds appreciably to the pressure, six practices have been used:

1. The pothead is filled with a highly viscous oil which has such high adhesion or surface tension that it prevents vacuum formation above the critical height while adding little to the head of oil.
2. The sheath is reinforced by bronze tapes or other material which is suitable in order to prevent stretching.
3. Oil migration between sheath and underlying layer is prevented by the use of clamps, with rubber cushions if the supports are liable to vibration.
4. A reservoir of oil is placed at the top of the riser and a receiving reservoir at the bottom of the riser so that a continuous drip of oil occurs.
5. A reservoir of nitrogen is placed at the top and an oil-receiving reservoir at the bottom of the riser, virtually converting the riser into a low-pressure gas-filled cable.
6. Cable is impregnated with a viscous stringy compound and operated at a temperature below that at which these characteristics are lost.

In connection with any of these expedients, a semistop joint is sometimes used near the base of a riser. A practical construction has blocked connectors covered with oil silk, sealed with oil-insoluble compound such as Harvel, Oil-Stop, Vinson Resin, or Minerallac and castor oil, varnished cambric insulating tape, and complete shielding. Where a reservoir is to be attached, a fluid oil compound is used; otherwise, an oil-insoluble solid-type compound.

The committee invites discussions giving, as far as possible, the following data:

1. Height of riser from base of pothead to lowest part of cable.
2. Distance (along cable) from base of riser to nearest joint.
3. Description of cable.
   - A. Conductor compact or uncrushed.
   - B. Number and size of conductors.
   - C. Thickness of individual tapes.
   - D. Total thickness of insulation.
   - E. Shielded or belted.
   - F. Type of binder tape.
   - G. Thickness of lead.
   - H. Cable diameter under lead.
   - I. Viscosity of impregnant over operating range or year and name of maker.
   - J. Reinforcement, if any, over sheath.
4. Type of supporting clamp, if any.
5. Range of ambient temperature.
6. Range of load.
7. Type of pothead and opinion of its gas tightness.
8. Type of pothead compound.
9. Pertinent conditions noted.

Digest of paper 50-258, "Terminal Risers for Solid-Type Impregnated Paper Cables," recommended by the AIEE Committee on Insulated Conductors and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23–27, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

W. A. Del Mar is with Phelps Dodge Copper Products Corporation, Yonkers, N. Y. He is chairman of the subcommittee of the AIEE Committee on Insulated Conductors (Power Division) which conducted this investigation. Other members of the committee were E. D. Bent, C. T. Hatcher, M. H. McGrath, J. H. Neher, G. B. Shanklin, F. V. Smith, R. J. Wiseman, M. Ghen, R. K. Woodson, and D. M. Farnham. Homer Martin also contributed useful data.

Field Testing a Microwave Channel

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COMMUNICATION CHANNELS, for transmitting the various types of intelligence necessary for operation of a power system, are becoming increasingly important to the utility industry because of the trend toward centralized system control. Pilot-wire and power-line carrier channels are already widely used to accommodate the many items of information necessary for efficient system operation. Microwave channels are the most recent addition to the means of communication available for this purpose.

A microwave channel[1] is a beamed high-frequency radio communication medium which can be used to transmit from point to point the intelligence required in the normal operation of a power system. Relaying, telemetering, supervisory control, and voice communication are some of the functions which can use such a channel. The large number of items of information which can be transmitted simultaneously over a microwave channel makes it particularly valuable at locations where communication traffic is heavy.

In order to provide a continuous path for the microwave installation between the Seward generating plant and the Johnstown plant of the Pennsylvania Electric Company's system, a reflector installation was used as line-of-sight was not available. This article describes the microwave channel and the terminal equipment.

It is the purpose of this article to describe an experimental installation of a microwave channel and terminal equipment which accommodates simultaneously three voice conversations, two different types of protective relaying, two telemetered quantities, and supervisory control of eight points. A feature of considerable interest on this installation is the use of a reflector to provide a continuous path for the microwave beam between the terminal stations, where line-of-sight was not available. The use of the reflector eliminated the need for $2\frac{1}{4}$ miles of cable originally planned to connect one of the terminal stations to a point where line-of-sight to the other station was possible.

The installation is on the system of the Pennsylvania Electric Company and ties together the main generating plant at Seward and the operating headquarters at Johnstown, Pa. A joint test program has been carried out during the past year by the Pennsylvania Electric Company and the Westinghouse Electric Corporation.

The Seward generating plant is the terminus for power-line carrier communications, telemetering, and supervisory control equipment for the entire power system. The efficient operation of the system depends on adequate and reliable communication facilities between the system operator in Johnstown, approximately 12 miles distant, and the Seward plant. The use of wire lines in the past has not been satisfactory because of outages and inferior service caused by extreme conditions, such as landslides, icing, automobile accidents, and gunshots.

The problem, therefore, was to prove that microwave and audio multiplex equipment provide a reliable channel which is suitable for voice communications, telemetering, supervisory control, and relaying. It was decided that three 2-way telephone circuits, two 1-way telemetering circuits, one 2-way supervisory control circuit, and two relaying circuits would be provided for in the tests.

A block diagram of the equipment located at each terminal is shown in Figure 1. The microwave equipment and audio multiplex equipment are suitable for transmitting four voice-frequency channels in each direction. Three of these channels are used for the telephone circuits and the fourth circuit has a number of tones applied to it which are keyed to perform the other functions. The microwave equipment and audio multiplex equipment provide the means for the simultaneous handling of the circuits required by the various functions being used in the field tests. The microwave transmitters and receivers with the associated antennas and the reflector provide a radio beam capable of modulation over a band of about 30 kc.

The multiplex equipment divides this broad band into several narrow bands by a system of frequency division. Each of these narrow bands can be used as a separate communication circuit and all can be used simultaneously. The equipment provides four such bands, but is capable of being extended to seven. Each band can be further subdivided by the use of audio-frequency tones to handle telegraphic types of service. The microwave and multiplex equipment is described in more detail in reference 2.

The directional-comparison-distance type[3,4] and the phase-comparison type[5] of "carrier" relaying are both used in this installation. The distance-type relays are connected to protect one of a pair of parallel 25-kv lines between Seward generating station and Broad Street substation, and the phase-comparison relays are connected to protect the other. The Broad Street substation is located remote

Essentially full text of paper 50-151, "Field Testing a Microwave Channel for Voice Communication, Relaying, Telemetering, and Supervisory Control," recommended by the AIEE Committee on Carrier Currents and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12–16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

One in a group of two articles on audio multiplexing equipment. The first was "Low Noise and Distortion Audio Multiplexing Equipment With High-Stability Carrier Supply," **F. A. Beale** (*EE, Nov '50, pp 968–73*).

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from the microwave equipment; therefore, the control circuits between the relays and the multiplex equipment are carried on underground control wires. In each case the signals required by the relaying system are transmitted and received on audio tones operating in conjunction with one of the subcarriers in the audio multiplex equipment, with the subcarriers in turn operating the microwave transmitter–receiver.

The units involved for the directional-comparison-distance type of carrier relaying are shown in block diagram form in Figure 2. In this case the audio tone is transmitted continuously during normal power system conditions, thereby providing continuous restraint on the receiver relay. The phase and ground relays are arranged to stop the tone transmission on the occurrence of an internal fault. This is the equivalent of a "continuous" carrier scheme as contrasted with the "intermittent" carrier scheme used in conventional carrier-relaying applications. A means of continuous supervision of the channel for transmitting signals required by the relays is provided by this method of operation. The transmission of a continuous signal also eliminates the necessity for the relays to start a blocking signal on external faults, and therefore, it is not necessary to set the third zone of the distance relays to "look out" of the protected line section as required of an intermittent carrier scheme. Loss of the blocking signal under normal system conditions would not result in an incorrect tripout, as the phase and ground relays supervise tripping, and would not operate unless a fault existed on the system within their setting range. Back-up tripping for phase faults is included in the phase relays. Back-up ground relays were not provided for the test.

The phase-comparison system of relaying,[5] when used over a microwave channel, is shown in the block diagram of Figure 3. The signals required by this relaying system are also handled on an audio tone. Since this is an intermittent carrier system, signals are transmitted only when a fault occurs on the power system. In addition, the blocks of "carrier" required for operation of this system must be transmitted at the power frequency. To accommodate this keying speed, a 2,900-cycle tone is used, and the control of this tone by the relays is through an isolating amplifier. Use of this relatively low frequency to carry the relaying signals resulted in a phase shift of about 55 degrees (60-cycle basis) in the received blocking signal and required the use of a delay filter in the circuit controlling the operating voltage of the relay. In other words, on an external fault, the half-cycle block of "carrier" initiated at one end of the protected line to block the opposite end from tripping, after going through the receiving equipment, would be 55 degrees behind the half-cycle block of operating energy and would depend on the phase position of the fault currents. This 55-degree shift could result in an incorrect operation on either an internal or an external fault.

Proper co-ordination of the relays for both the directional-comparison and phase-comparison systems using audio tones as the means of transmitting the necessary intelligence has been thoroughly checked on an artificial transmission line in the laboratory. Confirmation of these results is expected in the field experience which will be gained from this installation. Staged fault tests are being planned to check the performance of the relaying equipments.

Impulse-rate-type (frequency) telemetering[6,7] of two kinds is used in the trial installation. The impulse-rate-type telemeter operating over a range of 40 to 200 impulses per minute is one kind, and an experimental electronic impulse-rate (or frequency) system operating over a range of from 600 to 1,200 impulses per minute (10 to 20 cycles per second) is the other kind. As shown in Figure 1, the former is operating over a 560-cycle audio-tone channel, and the latter over a 1,080-cycle channel. The telemetering transmitters key the audio-tone transmitters, and the telemetering receivers are fed from the audio-tone receivers. Both transmitters are located at Seward generating station and the receivers are at Johnstown.

Two types of supervisory control systems[8–12] are used in this trial installation. One is the standard Visicode system and the other is the revertive-pulse type as described in

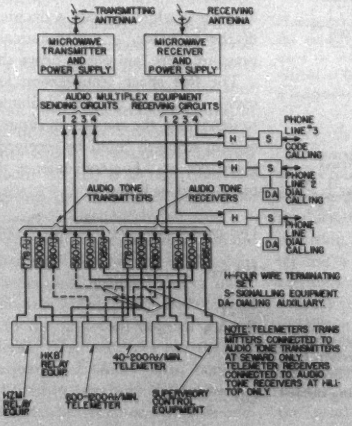

Figure 1 (right). Block diagram of the microwave, multiplex, communication relaying, telemetering, and supervisory control equipment used at the Seward and Johnstown (Hilltop) terminals of the experimental microwave channel. The telemetering transmitters are located at Seward and the receivers are at Johnstown

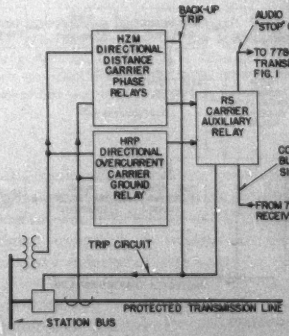
BACK-UP TRIP
AUDIO TONE "STOP" CIRCUIT
HZM DIRECTIONAL DISTANCE CARRIER PHASE RELAYS
TO 778 A/ TONE TRANSMITTER IN FIG. 1
RS CARRIER AUXILIARY RELAY
HRP DIRECTIONAL OVERCURRENT CARRIER GROUND RELAY
CONTINUOUS BLOCKING SIGNAL
FROM 778 A/ TONE RECEIVER IN FIG. 1
TRIP CIRCUIT
PROTECTED TRANSMISSION LINE
STATION BUS

Figure 2 (above). Block diagram of system required by a directional-comparison-distance type of carrier relaying over a microwave channel

reference 13. Both are all-relay systems which provide for the control of any required number of individual pieces of equipment. The relays originate and receive impulses in coded groups to select the equipment to be controlled, to perform the operation, and to provide an indication that the operation has taken place. Indications are provided also in the event of automatic operation of equipment.

An 8-point supervisory control assembly is used to control six 25-kv circuit breakers at Seward and to provide telemetering of alternating voltage and current from Seward to the dispatcher's office. Figure 1 shows that the supervisory control equipment operates over 1,500- and 2,085-cycle audio-tone channels. In general, any tone frequency within the audio spectrum may be used. However, the speed of pulsing may make some frequencies at the lower end of the band undesirable.

Supervisory control has previously been used in conjunction with microwave equipment on an experimental installation made in 1943 on a frequency of 530 megacycles.[9] In this installation direct keying of the high frequency was used, as contrasted with the use of an audio-tone channel working through audio multiplex equipment in the present installation.

The selection of antenna sites required considerable study, since microwave equipment requires a line-of-sight transmission path from the transmitting antenna to the receiving antenna. In addition, in order to eliminate serious fading, the line-of-sight path should clear all obstacles by at least 50 feet. The topography between Johnstown and Seward showed that the line-of-sight path between the system operations office and the Seward plant goes about 1,000 feet underground. This ruled out the use of a direct path between the two points. Study of the terrain and charts indicated that a line-of-sight path did exist from a 200-foot tower at the Hilltop substation near Johnstown (Figure 4) to a property at Armagh which was about 2.5 miles from the Seward plant. Further investigation of maps and terrain located a relatively inaccessible knoll which had line-of-sight paths to both Hilltop and the Seward plant. A repeater station located at this point would have satisfactory path clearance to both terminals. However, the lack of an available source of power, and inaccessibility of this location in bad weather, led to the consideration of a reflector instead of an electronic repeater. Since there was no previous information available upon which to base a decision as to the practicability of the reflector, a mathematical analysis and field test program were laid out to prove the application.

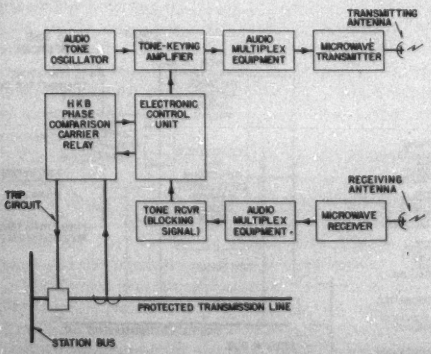

Figure 3. Block diagram of the components to obtain the communication facilities required by a phase-comparison type of carrier relaying over a microwave channel. This is an intermittent system with the relaying intelligence being carried over a 2,900-cycle audio-tone channel

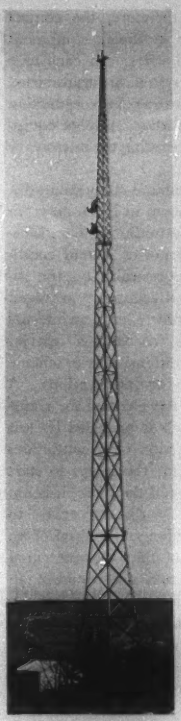

Figure 4 (left). The 200-foot-high frequency-modulated transmitting tower at Hilltop Substation, showing the microwave transmitting and receiving antennas mounted about three-fourths of the way up

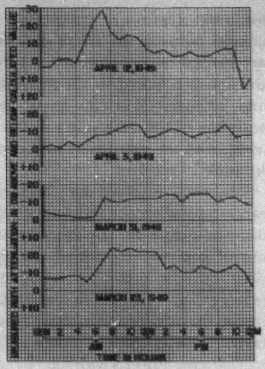

Figure 5 (above). Comparison of the measured and calculated path attenuation between Armagh and Hilltop. The distance is 11.3 miles, frequency is 955.5 megacycles, and antenna gain is 58. Levels above zero line represent lower losses than calculated

The free space transmission loss of microwave energy over a given path can be calculated from formulas[13] derived to determine the maximum range over which a signal of a certain strength could be received from a transmitter of a given power. For convenience these formulas have been rearranged as follows:

$$\text{Free space transmission} = 10 \log_{10} \frac{P_T}{P_R} \text{ decibels} \tag{1}$$

Where

$$\frac{P_T}{P_R} = \left(\frac{4\pi R_0}{\sqrt{G_T G_R}\,\lambda} \right)^2 \tag{2}$$

and

$$G = \frac{4\pi A_{eff}}{\lambda^2} \tag{3}$$

Where transmitting and receiving antennas are identical, equation 2 reduces to

$$\frac{P_T}{P_R}=\left(\frac{4\pi R_0}{G\lambda}\right)^2 \tag{4}$$

where P_T = transmitter power in watts, P_R = received power in watts, R_0 = distance between antennas in meters, G_T = gain of transmitting antenna, G_R = gain of receiving antenna, λ = wave length in meters, G = antenna gain, and A_{eff} = approximately one-half of the projected area of the antenna in square meters.

The total loss between a transmitter output and a receiver input includes other factors in addition to the free-space transmission loss. In planning an application, allowance must be made for fading and transmission-line (in this case coaxial cable) losses between the equipment and the antennas.

The amount of fading that can be expected is a function not only of the amount of clearance obtained along the transmission path, but also of the weather. Fading is most severe during the summer months. Based on data previously taken,[14] a fading-loss figure of one-half decibel per mile is used for planning 940- to 960-megacycle installations, and this much fading is expected to occur only one per cent of the time. Transmission-line (coaxial cable or the equivalent) loss depends on the type of transmission line and its length. The total loss for a given installation can be predicted by adding the free-space transmission loss, the fading loss, and the transmission-line loss.

As an example, assume two 950-megacycle equipments with 42-inch diameter antennas located 20 miles apart, having a line-of-sight path with 50-foot clearance over all obstacles, 100 feet of transmission line at each terminal using *RG-17/U* coaxial cable. The following maximum attenuation would exist:

Free space transmission loss	= 87.1 decibels
Fading loss (20 miles by $^1/_2$ decibel per mile)	= 10.0 decibels
Transmission-line loss	= 8.0 decibels
	105.1 decibels

These losses can be decreased by any or all of the following: increasing the size of antennas, using lower-loss transmission line, and mounting the equipment closer to the antennas. Where the loss between two terminals exceeds the permissible ratio between transmitter power output and minimum receiver input power, the transmitter output power can be increased or repeater stations installed. Where no line-of-sight path exists, reflectors can be used if the additional loss caused by the reflection does not increase the path loss beyond the maximum permissible attentuation for the equipment being used.

The increase in path transmission loss caused by the use of reflectors can also be calculated. In making calculations involving the use of reflectors, it is assumed that a plane reflector acts in the same manner as two parabolic antennas having areas equivalent to the projected area of the reflector in the two directions. The path loss can then be calculated by applying equation 2 twice: first, between the transmitter and the reflector to determine the equivalent amount of energy received at the reflector; and second, between the reflector and the receiver assuming that the reflector acts as a transmitter.

For a single reflector, equation 2 can be expanded to give directly the ratio of transmitter power to receiver input power

$$\frac{P_T}{P_R}=\left(\frac{16\pi^2 R_1 R_2}{\sqrt{G_1 G_2 G_3 G_4}\,\lambda^2}\right)^2 \tag{5}$$

where R_1 = distance from transmitter to reflector in meters, R_2 = distance from reflector to receiver in meters, G_1 = gain of transmitting antenna, G_2 = equivalent gain of reflector in direction of transmitter, G_3 = equivalent gain of reflector in direction of receiver, G_4 = gain of receiving antenna, and λ = wave length in meters.

The preceding equations were used to calculate the expected loss with reflector between Hilltop and Seward. From equation 5 the loss was calculated to be 115 decibels. This corresponds to the zero levels shown in Figure 5. The calculations also showed that a 20-foot square reflector would be required to meet this figure of 115 decibels. This would provide adequate margin of safety over the permissible path loss of 125 decibels with the type of microwave equipment being used. However, before proceeding with a permanent installation of a reflector, it was decided that a test program would be carried out to determine the variation in signal strength at the reflector location and to try out a temporary reflector 20 feet square to check the calculations.

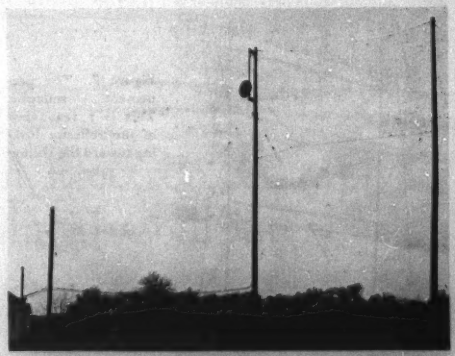

Figure 6. The temporary reflector at Armagh used to check the calculations. The dish antenna on the left-hand pole was used in obtaining the data for Figure 5. The garage partially visible at the left was used to house the terminal equipment, and a temporary power line was constructed to supply the power for the equipment

A microwave transmitter-receiver assembly was installed at Hilltop substation and another at Armagh with recording voltmeters indicating received signal strength at Hilltop. Continuous recordings of field strength were made for a 6-week period. These data were converted into terms of the total attenuation between transmitter output and

receiver input and an analysis was made by taking readings once an hour for the period.

A comparison between the measured data and the transmission loss calculated from the given formulas was made using measured values for coaxial cable losses. The following conclusions were reached:

1. That the measured path attenuation did not exceed the calculated data for more than 0.99 per cent of the hours during which data were taken. These calculated data included an allowance for fading of one-half decibel per mile of path.
2. That the measured path attenuation did not exceed the calculated data for more than 3.87 per cent of the time if no allowance for fading is made in the calculated data.
3. That although the maximum attenuation figures were not greater than would be expected from the calculations, the minimum attentuation figures were considerably less than would be expected.

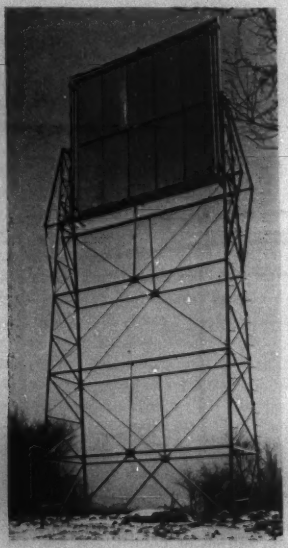

Figure 7. The permanent reflector. This is a rear view of the reflector looking toward the Hilltop substation

The signal strength was found to vary considerably during a day. A plot of the hourly variation for several typical days during the test period is shown in Figure 8. The average level at the receiver was considerably greater than expected and fading about this average level was also greater than expected. The wide variations due to fading were attributed to multipath transmission of signals to the receiver, with alternate cancellation and reinforcement, possibly due to the terrain as the several signals went in and out of phase.

Based on the measured data it appeared feasible to use a reflector in order to get the signal to the Seward generating plant, providing 6-foot diameter antennas were used at each terminal.

The first step in the reflector test program was to install a receiver and a 42-inch receiving antenna at Seward to determine if a signal reflected from natural surfaces was being received from Hilltop. In a series of tests made over a 2-day period, no measurable signal was received from any direction or at any polarization. Next, a signal was transmitted from the Armagh transmitter and the signal level was checked at Seward. The measured loss was quite high indicating that line-of-sight did not exist, even though a study of the topographical maps had showed clear line-of-sight. It was decided, however, to install the temporary reflector, Figure 6, at Armagh and check the reflected signal level at two points on the highway where line-of-sight to the reflector could be obtained. This necessitated mounting the receiving equipment in a light truck equipped with a motor generator set so that readings could be taken at the side of the highway. The following results were obtained:

1. The measured beam width of the energy reflected from the screen was 2.4 degrees.
2. The total measured path attentuation to a point 2.75 miles away from the reflector (total path 14.05 miles) was approximately 115 decibels which is ten decibels less than the maximum permissible with type-*FB* equipment.
3. Additional tests were made at a point 3.75 miles from the reflector where the maximum attentuation was approximately 133 decibels. Under these conditions, voice communication over the circuit was very good, with slight noise in the background.

Based on the previous calculations and field data, it was decided to install a permanent reflector made of perforated sheet aluminum. This reflector is shown in Figure 7. It is mounted in a different location than the temporary reflector of Figure 6, and has a clear line-of-sight path to both Hilltop and Seward. The tower support is 60 feet high and the center of the 20-foot square reflector is 50 feet from the ground. The reflector and tower are designed for use in 100-mile per hour winds and in 60-mile per hour winds with an ice coating which closes up the perforations. Because of the sharp beam of energy reflected from a surface of this size, it is of utmost importance that the reflector be positioned so a perpendicular to its center bisects both the vertical and horizontal angles subtended by the antennas at the terminal stations. For ease of this adjustment the reflector is mounted in gimbals, which permit it to be moved as much as plus or minus ten degrees in both vertical and horizontal planes.

During the test period it has not been necessary to replace any tube on an emergency basis. No internal defects have developed such as a short circuit between tube elements or an open heater.

The experience to date on tube life is not conclusive, but indications are that satisfactory life will be obtained. The microwave portion of the equipment has been operating continuously since February 1949 and replacement of tubes has been at about the same average rate as for power-line carrier and mobile radio equipment. There have been

no component failures. The multiplex equipment has been in operation since August 1949 with similar experience.

A direct lightning strike on the tower at Hilltop had no effect on the operation of the microwave equipment. Operation was not affected during the worst conditions of weather including heavy snow, sleet, and rain, indicating that sufficient margin of safety has been used. It is interesting to note that the maximum variation in path attenuation occurs on clear days in the morning and evening hours, and this is apparently the result of temperature inversion.

Data on noise and crosstalk, and distortion on the three telephone channels obtained by the microwave and the audio multiplex equipment, are given in Table I.

Table I. Data on Noise, Crosstalk, and Distortion

Telephone Channel	Noise and Crosstalk, Decibels Below One Milliwatt	Distortion
1	−41	Less than one per cent
2	−40	Less than one per cent
3	−43	Less than one per cent

The audio level of the three multiplexed channels is not over six decibels down from response at 1,000 cycles, at 250 cycles, and at 2,800 cycles.

REFERENCES

1. Microwave Channels for Power System Applications, **AIEE Committee Report.** AIEE *Transactions*, volume 68, part I, 1949, pages 40–2.

2. A Low Noise and Distortion Audio Multiplexing Equipment With High-Stability Carrier Source, **F. S. Beale.** AIEE *Transactions*, volume 69, part II, 1950, *pages 1028–38.*

3. A Distance Relay with Adjustable Phase-Angle Discrimination, **S. L. Goldsborough.** *Electrical Engineering* (AIEE *Transactions*), volume 63, November 1944, pages 835–8.

4. A New High-Speed Distance-Type Carrier-Pilot Relay System, **E. L. Harder, B. E. Lenehan, S. L. Goldsborough.** *Electrical Engineering* (AIEE *Transactions*), volume 57, January 1938, pages 5–10.

5. A New Carrier Relaying System, **T. R. Halman, S. L. Goldsborough, H. W. Lensner, A. F. Drompp.** *Electrical Engineering* (AIEE *Transactions*), volume 63, August 1944, pages 568–72.

6. An Improved High Rate Impulse Telemeter System, **C. Oman.** *Electric Journal* (East Pittsburgh, Pa.), August 1934, page 313.

7. A Telemeter Transmitter Without Moving Contacts, **C. Oman.** *Westinghouse Engineer* (East Pittsburgh, Pa.), May 1948, page 92.

8. A Self-Checking System of Supervisory Control, **M. E. Reagan.** *Electrical Engineering* (AIEE *Transactions*), volume 57, October 1938, pages 600–05.

9. Channels for Operation of Supervisory Control Equipment, **W. A. Derr, M. J. Brown.** AIEE *Transactions*, volume 67, 1948, pages 1654–60.

10. By a Flick of the Finger (Supervisory Control), **W. A. Derr.** *Westinghouse Engineer* (East Pittsburgh, Pa.), November 1949, page 162.

11. The Combination of Supervisory Control With Other Functions on Power-Line Carrier Channels, **R. C. Cheek, W. A. Derr.** *Electrical Engineering* (AIEE *Transactions*), volume 64, May 1945, pages 241–6.

12. A New Two-Signal Synchronous Supervisory Control System, **W. A. Derr.** AIEE *Transactions*, volume 68, part II, 1949, pages 857–63.

13. Propagation of Very Short Waves, **D. E. Kerr.** *Electronics* (New York, N. Y.), January 1948, page 124.

14. Microwave Propagation Tests Over 40 Miles Overland Path, **A. L. Durkee.** *Proceedings*, Institute of Radio Engineers (New York, N. Y.), February 1948, page 200.

The Graph-Scope, an Electronic Graph Plotter and Graphical Computer

A. L. THOMAS, JR.
ASSOCIATE AIEE

This article describes an electronic instrument which draws a graph with any number of co-ordinate lines. Points may be plotted on the graph by punching the data into a keyboard, and curves are drawn with an analogue computer. The type of co-ordinate system may be switched from linear to logarithmic or hyperbolic without replotting the points. An automatic photographic recording system may be employed and the whole device provides a rapid graph-plotting facility.

THE GRAPH-SCOPE is an electronic graph plotter which is designed to provide for the research worker a facility for plotting data which is equal in refinement to those facilities with which he obtains data. In the design of the Graph-Scope four aims have been primary: to provide great flexibility in the finished picture, to reduce the chance for human error, to reduce graph plotting time, and to reduce the eyestrain involved in the usual point plotting on graph paper.

The television scheme is used in the Graph-Scope to provide a rectangular scan with which the co-ordinate lines are drawn on a cathode-ray tube. On the graph sheet thus formed the operator may plot points and curves according to his experimental data. If the data are believed to follow some mathematical law, a standard curve may be generated with an analogue computer and the parameters adjusted until the curve fits the plotted data points. Then the expression may be written down after reading the dials. If it is desired, the graph may be switched to semilog, log-log, or hyperbolic scales without the necessity of having to plot the points again.

A keyboard like that of a calculator is used for setting the point-plotting circuits, and the answer tube may be viewed by projection and photographed by one of the rapid automatic systems.

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The Graph-Scope will draw its own co-ordinate system with: any number of divisions of either axis; any number of lines between major lines; any length of either axis; any slope of either axis; linear, logarithmic, or hyperbolic division of either axis; and rectangular or polar plot. It plots on the co-ordinate system any moderate number of points with: correct position for all types of plots, brightness control of each point and each group of lines, a remote keyboard system for plotting points, and a manually adjusted point for sampling a particular value. When used in conjunction with an analogue computer, the Graph-Scope will draw on the same graph any of the standard mathematical functions with calibrated and adjustable parameters.

ELECTRONIC SYSTEM

The cathode-ray tube display used in the Graph-Scope is very much like that used in television. The beam is caused to sweep in one direction very slowly and in the other very rapidly, sweeping out a rectangular area on which the graph is drawn by presenting to the grid of the cathode-ray tube a series of pulses. Figure 1 shows the beam trace and a part of the grid signal expanded in the *X* direction, and Figure 2 shows the primary wave forms of interest in the Graph-Scope.

Further extension of the pulse-timing system can be made to allow the graphing of continuous curves. In all of these pulse-generating and timing operations a saw-tooth voltage is used as a transfer function from direct voltage to pulse time to spot position. The block diagram, Figure 3, shows the electronic components and their arrangement. A fast pulse source and a slow pulse source keep the operations synchronized in each direction of the sweep. The sweep circuits generate sweeps any desired number of pulse periods long, and the sweep signals are then controlled by special sweep amplifiers. Point plotting is done by recognizing when a linear negative saw tooth has reached the value of direct voltage which corresponds to the datum value, a positive pulse being added to the scope grid signal at that time. A dynamic plotter is used to plot curves, the reference potential being the signal corresponding to the curve it is desired to plot. In this manner, the Graph-Scope can be used as a multi-input scope for signals of the same frequency, each one being presented to a different dynamic point plotter. The curve will be given proper spacewise presentation if its voltage function is synchronized to the slow sweep. Notice that the points are plotted with respect to the lines regardless of the type of sweep function. Thus, there is the opportunity to use logarithmic or hyperbolic sweep functions to present the data in the manner which best reveals its properties.

It is desirable to make the picture repetition rate as fast as possible in order to improve the resolution when a periodic function is being viewed on the Graph-Scope. If the repetition rate is 50 per second and a 500-cycle wave is viewed, there will be ten cycles closely spaced on the graph. But if the repetition rate were 500 per second, there would be one spread-out wave on the graph. The slow sweep may be synchronized to the voltage function if its period is an integral number of pulse periods. Otherwise, the slow pulse rate will have to be changed to match the signal, thus changing the calibration of the point plotters.

The upper limit of the time scale is the response rate of the pulse-operated circuits and pulse source. The general scheme must be proved at a minimum cost; therefore, simple circuits and common tubes must be used. In generating fast pulses it is necessary to have the pulse

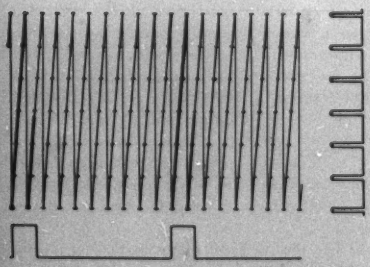

Figure 1 (above). The sweep trace and the grid signal, expanded in the *X* direction, showing how the co-ordinate lines are drawn

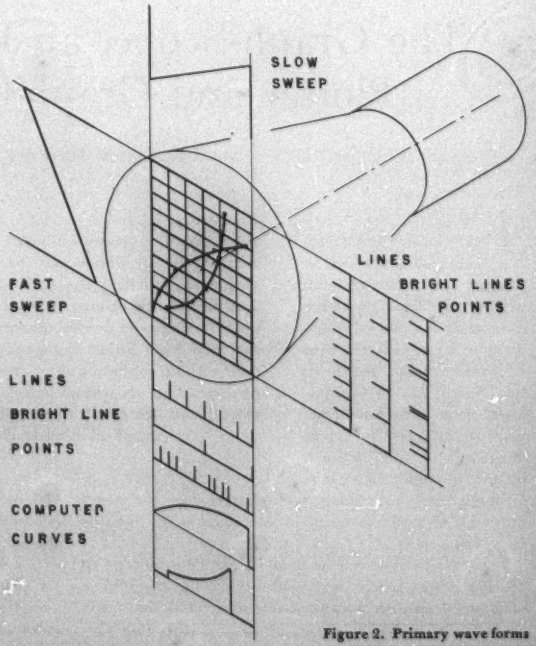

Figure 2. Primary wave forms

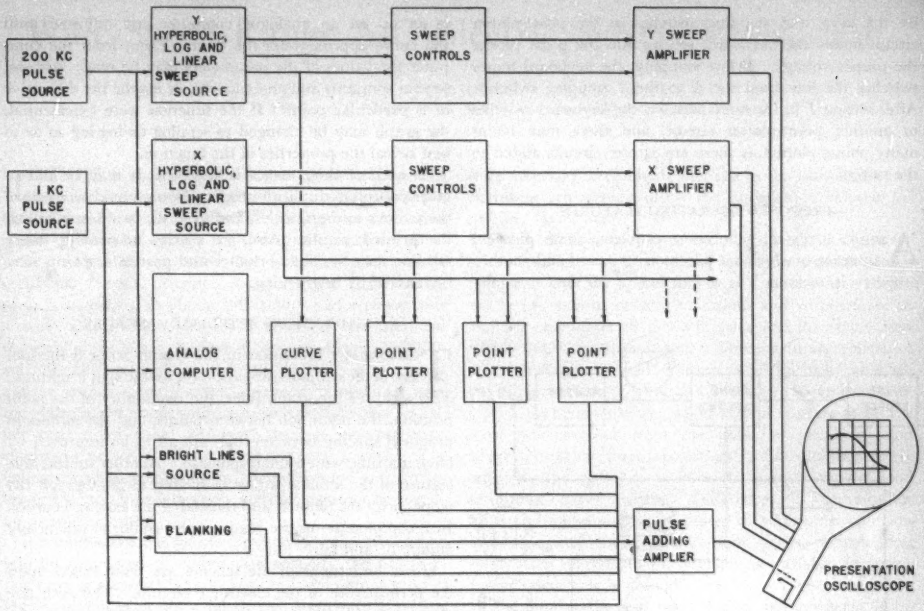

Figure 3. Block diagram of the Graph-Scope

width a small part of the time between pulses in order to draw fine co-ordinate lines. A typical set of time-base intervals which has been used is a pulse width of 0.5 microsecond and a pulse interval of five microseconds. Then, if the maximum number of lines desired is 20, the longest vertical sweep time would be 100 microseconds. To provide a reasonably solid screen, the slow pulse interval should include ten fast sweeps or 1,000 microseconds. Then the longest slow sweep desired would be 20,000 microseconds, giving a minimum picture repetition rate of 50 per second. In normal operation the fast and slow pulse-repetition frequencies are set at random so that the vertical sweeps will always drift rapidly with respect to the vertical lines as turned on by the slow pulses. Thus, the vertical lines are made to appear solid, and there is no limit on the resolution of spot position as there would be if the traces were fixed in position, leaving some blank stripes on the field.

The fast and slow channels are practically the same in all properties except the time constants involved. In the slow channel a broader pulse is needed than in the fast in order to have the vertical lines appear continuous. A simple free-running blocking oscillator provides a stable enough pulse source at about 200 kc but large pulse-repetition frequency changes would change the calibration of the point plotters. For the 1-kc pulse source an asymmetric multivibrator is used. Figure 4 shows how the sweep time is caused to be any integral number of pulse periods. To increase the number of lines on the graph it is only necessary to run down the bias on the clipper circuit.

Assume now that a saw-tooth wave has been generated in the same manner at the slow rate. The pulses of each frequency are drawing co-ordinate lines on the scope, as in Figure 3, and the next process is that of timing a pulse so that it will plot a point on the graph. The sweep is used as a transfer function with which to derive a pulse whose time is proportional to a direct potential. Every time the fast sweep falls to the set voltage, a pulse is delivered. The string of fast pulses from the Y channel is below the bias level of the clipper until a slow pulse is added from the X channel, giving one properly timed pulse. This, and all of the other point-plotting and line-drawing pulses, are added and presented to the grid of the scope. Figure 5 shows the scheme of the point-plotter circuit.

Calculating machines have proved the value of the keyboard for handling numbers, and many people have been trained to use them rapidly. Therefore, the keyboard mechanism was selected for putting data into the graph plotter.

The function of the keyboard in this application is just like that of the dial in the automatic telephone system. In this graph plotter the problem is to switch remotely the inputs of the X and Y point plotters to direct potentials which correspond to the values of the data. A number for X is punched into the board, the motor is actuated, the shafts under the keys rotate decade switches until stopped

by the keys, and stepping switches in the point-plotter circuit follow the keyboard, setting into the point plotter the proper voltage. Before stopping, the keyboard motor switches the line from the X to the Y stepping switches. After setting Y in the same manner, the keyboard switches to another point-plotter circuit, and there may be as many points plotted as there are plotter circuits added to the system.

PROPOSED OPERATING FEATURES

Assume a typical laboratory problem, some physical situation in which one parameter is varied and another property is measured as a function of the first. As the values are set and read, they are punched into the keyboard of the Graph-Scope. A plotted point appears each time the keyboard is actuated until presently the data being read have become larger than the graph. By turning two dials, more lines may be placed on the graph to just include the data, yet provide the largest possible scale. Discontinuities and erroneous readings may be observed while the data are being read.

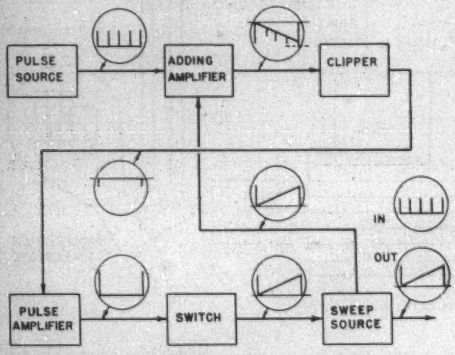

Figure 4. Pulse counter and sweep generator

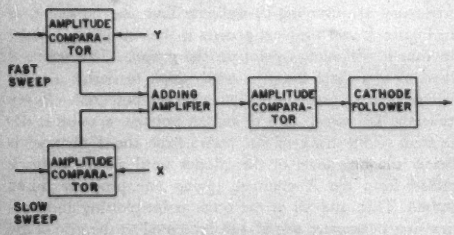

Figure 5. Point plotter

After the physical conditions of the problem have been carried through their range, the points plotted may appear to follow some mathematical law. The suspected function is set up on an analogue computer and adjusted until the curve approximates the data. Then, from the computer the values of the parameters may be read; such as, several constants and an exponent, or maybe the derivative at a particular point. If the function were exponential, the graph may be changed to semilog or log-log so as to best reveal the properties of the function.

As each of these stages is observed, it may be photographed from a duplicate scope. Notes should be made of the various settings, scales, and so forth, to aid in labelling the printed graphs. Also, for clarity in reading, every nth line may be made brighter and particular points may be marked by brightening.

LIMITATIONS AND DISADVANTAGES

The primary limitation in the Graph-Scope is the spot size of the cathode-ray tube for a usable spot brightness. The width of the graph lines, the readability of the point position, the resolution between points, and the minimum practical spacing between lines are all to be improved by having a tube with a small spot size. Another undesirable feature of the scheme is that of having to photograph the scope, print the picture, and then label the axes and curves. In a complete setup the photography could be practically automatic and fairly fast.

Other limitations of the scheme are those based upon the performance of the electronic circuits. The accuracy of position of the plotted point and the accuracy of spacing of the co-ordinate lines are both related to the linearity of the saw-tooth generator, probably about 0.1 per cent with very good circuit design. If a large number of lines is desired, the accuracies of line spacing and point position must be sacrificed because the voltage wave forms may be linear only over a limited range unless large tubes and expensive circuits are employed. Thus, the accuracy of performance of the device is seen to be determined to a large extent by the amount of money which has been devoted to the effort.

The first observation to be made is that the electronic scheme has been tried and found to provide the desired degree of flexibility. In plotting the graph, no time is wasted in selecting the paper or the scale because the proportions of the picture may be adjusted after the data have been put into the plotter.

Each of the other objectives has been met also. By having the operator plot the data with a keyboard instead of looking directly at the lines of the graph, much time is saved, and the eyestrain and possibilities of human error are greatly reduced.

In addition to graph plotting, the machine was found to be easily adapted to graphical computation. Also, the electronic co-ordinate system greatly enhances the value of the answer from an electric analogue computer, providing direct reading of any value of the computer answer.

REFERENCES

1. Waveforms (book), **B. Chance, V. Hughes, E. F. MacNichol, D. Sayre, F. C. Williams.** Massachusetts Institute of Technology (Radiation Laboratory Series), McGraw-Hill Book Company, Inc., New York, N. Y., 1949.

2. Microwaves and Radar Electronics (book), **E. C. Pollard, J. M. Sturtevant.** John Wiley and Sons, Inc., New York, N. Y., 1948.

Wide-Speed-Range A-C Electric System for Aircraft

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THE USE of variable-frequency a-c generating systems on aircraft has increased greatly in the last few years. One excitation scheme for these generating systems consists of a d-c generator exciter, built integrally with the alternator, which is controlled by a carbon-pile voltage regulator. Special attention must be given to the design of such an exciter to obtain satisfactory performance over a wide speed range. Figure 1 shows a cross-sectional drawing of a 30-kva 3-phase 0.9-power factor 208/120-volt 400/800-cycles-per-second 4,000/8,000-rpm alternator and its exciter. Satisfactory operation is obtained over the entire speed range with load varying from zero to 150 per cent rated value and with various environmental conditions as are encountered on military aircraft. The voltage-regulating controls for this alternator and exciter are similar to those commonly used for constant-frequency a-c power systems.

It is imperative that certain factors concerning the carbon pile be considered to co-ordinate properly the design of this type of system. The maximum-to-minimum ratio of regulator resistance must not exceed approximately 30 to 1, nor should the average voltage per disk in the pile exceed a maximum of one-half volt. A properly designed anticipating circuit is used to stabilize the system during transient conditions.

In the design of the d-c integral exciter it is essential to consider the desired shape of the load saturation curves. Wide-speed-range operation results in very low excitation voltages at the higher speeds. It is necessary that the load saturation curves in the operating range always have a decreasing slope in the direction of an increase of exciter field current. The shaping of the curves to obtain such characteristics required several exciter modifications on the 30-kva machine. The final design differs from the original design in that shims were installed under the main poles, the width of the main poles was decreased, and the pole-face windings were increased to balance completely the armature reaction. These changes were necessary to eliminate the dips in the load saturation curves which were causing the undesirable voltage instability under load.

The final design of this self-excited exciter and alternator in combination with their voltage regulator provides voltage regulation over the operating range of the machine within $\pm 2^1/_2$ per cent at normal conditions and within three to four per cent under all environmental and load conditions which might be encountered. The maximum resistance of the field circuit was 18 ohms at 10,000 rpm, no load; the minimum was 5.5 ohms at 4,000 rpm, 150 per cent load.

This particular electric power system appears to be the most advantageous from the point of simplicity and weight; however, there is considerable difficulty in properly adjusting the exciter to provide the suitable type of load saturation curve desired. Differences in commutator films and commutation qualities, in addition to the unavoidable brush movements at high speeds, indicate that some other solution to the problem of variable frequency power in aircraft is desired.

The pilot exciter and main exciter power system is inherently more stable than one without a pilot exciter, and it eliminates the danger of polarity reversals. The recovery time of the system would be shorter than that of a system without a pilot exciter because of the constant voltage available for supplying the main exciter field.

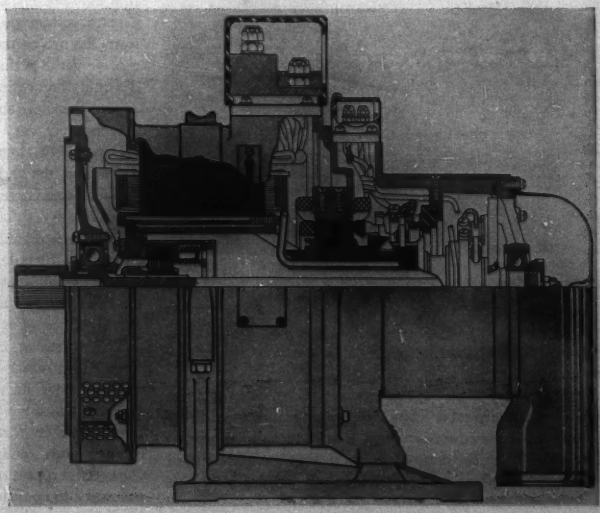

Figure 1. Cross-sectional view of 30-kva 3-phase 208/120-volt wide-speed-range aircraft alternator and exciter

Digest of paper 50-276, "Wide-Speed-Range A-C Electric Systems for Aircraft," recommended by the AIEE Committee on Air Transportation and approved by the AIEE Technical Program Committee for presentation at the AIEE Middle Eastern District Meeting, Baltimore, Md., October 3–5, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Unionmelt Voltage Controls

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Three different voltage controls are used with Unionmelt welding processes. They are the electronic control, the series control, and the air control. These controls have been designed to be used with either alternating or direct welding current, and they act on the principle that the arc voltage varies with the distance between the end of the rod and the work.

WHEN THE submerged melt welding process was first introduced 15 years ago, one of its most attractive features was the extremely large welding currents that could be used for making heavy welds in one pass. At that time there were a number of automatic welding machines available for arc welding with bare-wire or coated electrode. None of these machines, however, had the capacity to handle the maximum welding currents and rod diameters usable with Unionmelt* welding. Consequently it was necessary to design new equipment which could handle currents up to 4,000 amperes and could feed coiled welding rod up to one-half inch in diameter.

There were, of course, other features of the process which made it desirable to develop more specialized automatic feeding and control devices than were then in existence. Since the operator could not see what was going on in the welding zone because of the cover of granular Unionmelt composition, it was necessary to use indicating meters and

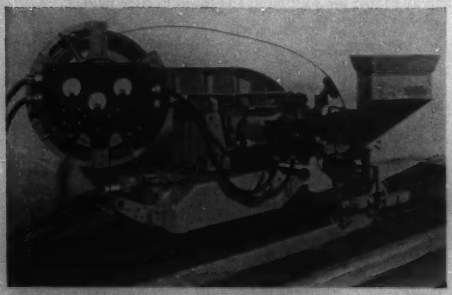

Figure 1. Heavy-duty portable welding machine showing the UE-type operating controls

to provide more accurate controls to maintain the proper welding conditions.

It was expected that the process would replace open arc welding on many jobs. Since either alternating or direct current can be used for welding, it was considered advantageous to design the control system so that it could be used with standard arc-welding generators or transformers, regardless of the type.

During the past 15 years, as Unionmelt welding became widely accepted by industry, it was applied to lighter weldments, and the need arose for smaller portable units which could be more easily operated and maintained. Consequently, at the present time there are three different controls and associated equipment in wide use. These three are generally spoken of as the electronic control, the series control, and the air control. All three systems, however, have certain basic features in common: they can be used with either alternating or direct welding current from any standard-type welding transformer or generator; they all function on the principle that, above a certain minimum, the voltage across an arc will vary in proportion to the distance between the end of the rod and the work. The controls are used to regulate the speed of the rod-feed motor and thus keep the welding voltage at the selected value.

Fundamentally, a welding-voltage control is simply an automatic speed-regulating device with a feedback circuit. Although many different types of such devices could possibly be used for a welding voltage control, certain requirements must be met to make them practical. One factor that may prevent a good speed-regulating system from being a good voltage control is that the signal voltage fed back from the arc contains false information and does not truly represent the action of the feed mechanism. For instance, if a metallic arc is operating at an average of 30 volts a-c, an oscillograph shows that each cycle of the alternating current may vary from 20 to 40 volts. These variations are probably caused by the manner in which the metal melts from the end of the welding rod. The voltage itself, if alternating current is used, is not a pure sine function, but it resembles a square wave, having a high ignition voltage at the start of each cycle. Voltage variations can also be caused by turbulence in the molten metal or in the arc stream from magnetic effects. A satisfactory control, therefore, should not have a response so sensitive or rapid that it will be affected by these factors.

The objective in designing a satisfactory control was simply to produce smooth, even welds with uniform penetration under normal welding conditions, rather than to satisfy a thorough mathematical analysis. In fact, it has been shown by a recording voltmeter or oscillograph that, in some cases, uniform welds can be made even though the voltage fluctuates quite widely. In the final design, it was necessary to consider the operation of the control unit and

* The term "Unionmelt" is a trade-mark of The Linde Air Products Company.

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the feeding mechanism. In developing the control an effort was made to keep the circuits as simple and straightforward as possible and to avoid any complicated circuits with numerous components or critical adjustments.

The electronic Unionmelt welding control is shown in Figure 1 mounted on a portable welding machine. This machine has welding current capacity up to 2,000 amperes and will handle rods up to 5/16-inch diameter. The welding head is equipped with a 1/4-horsepower rod-feed motor, although the control has sufficient capacity to supply a 1/2-horsepower motor. The complete control is in three units, interconnected by means of multiconductor plugs and receptacles for ease of servicing and moving the machine from one location to another.

The main unit, not shown, is a box about one foot by one foot by two feet which houses the electronic tubes, transformers, and associated components. It is generally mounted near the welding transformer or generator. The two other units are shown in Figure 1. On the left is the remote-control panel which contains single adjustments for welding current and voltage, together with meters for indicating these values. A meter showing travel speed is also included. On the right is the switch box containing the switches for manually controlling the welding operation.

In actual practice, the operation is quite simple. The operator first eases the rod into contact with the work. He then opens a spout from a hopper to release the granular welding composition which covers the end of the rod and the surrounding area of the work piece. He then presses the "start" button. This automatically throws on the welding current, retracts the rod, and puts the travel carriage into motion. At the end of the weld the operator throws a toggle switch which stops the travel, stops the rod feed, and allows the end of the rod to melt off. The welding voltage rises and a relay automatically disconnects the welding current supply. At no time is open-circuit voltage applied to the machine except when the start button is manually held closed.

The basic circuits of the electronic control are shown in

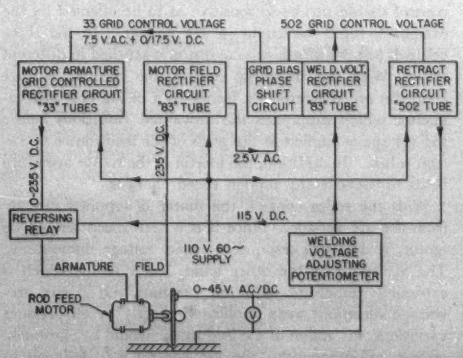

Figure 2. Basic circuits for the electronic control. Three of the rectifier circuits are supplied from a 110-volt a-c line while the fourth is supplied from the voltage across the welding zone

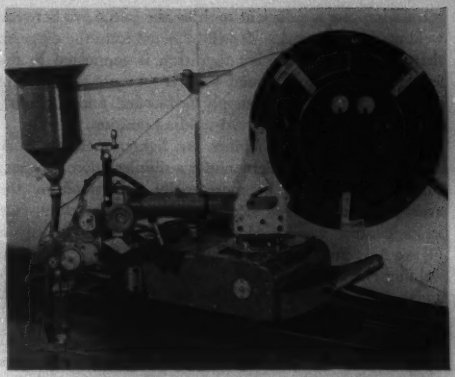

Figure 3. Medium-duty portable welding machine with series-type control handles welding currents up to 1,200 amperes

the circuit diagram in Figure 2. It will be seen that the control consists of four rectifier circuits, three of which are supplied from a 110-volt a-c line, and the fourth from the voltage across the welding zone. The line voltage is converted by one rectifier circuit to 235 volts d-c with the use of a step-up transformer and a full-wave rectifier to supply the field of the rod-feed motor. This voltage remains fixed.

The armature of the motor is also supplied from the 110-volt line through a step-up transformer and a pair of thyratrons. The output voltage of the thyratrons may vary anywhere between 0 and 235 volts d-c, depending upon the control voltage applied between the grid and cathode of the thyratron tubes. The control voltage applied to the grids of the thyratrons is the sum of the rectified welding voltage and a small a-c bias voltage which is 90 degrees out of phase with the plate voltage of the thyratrons. This is commonly known as a quadrature phase-shift circuit and is used to valve the output of thyratron tubes in proportion to a d-c signal voltage.

In the control under discussion, the a-c bias is fixed so that the output voltage for the feed-motor armature can be varied from 0 to 235 volts by varying the signal (welding voltage) from about 15 to 20 volts. By using a potentiometer to adjust the output of the welding voltage within this 5-volt range, the speed of the rod-feed motor can be set at any rate for any particular welding voltage within the normal welding range of 20 to 45 volts. If, for some reason, the welding voltage tends to increase, the feed motor will speed up slightly to compensate for the change. If the welding voltage decreases, the motor will slow down.

The fourth rectifier circuit in the control consists of a small thyratron tube which supplies a reversing relay in the feed-motor armature leads. This is used to start the weld by momentarily retracting the rod. When starting a weld, the rod is placed in contact with the work and the welding-current circuit is closed. At this instant the reversing relay closes, the leads to the armature are reversed, and the feed motor retracts the rod. This short

retract impulse is sufficient to draw the initial arc between welding rod and work. It will be noted from the diagram that the grid of the relay thyratron is connected to the feed-motor armature circuit so that as soon as armature current flows the relay supply is blocked and the relay returns to its normal forward-welding position.

As the need for machines for lighter welding work increased, there was a demand for a simpler, more compact control which could be more easily understood by the average plant-maintenance personnel. Therefore, the series control was developed. This control, shown in Figure 3, is used with a welding machine that will handle welding currents up to 1,200 amperes and rod up to one-fourth inch in diameter. The welding head has a 3/8-horsepower 32-volt universal rod-feed motor. The complete control is usually mounted in the center of the rod reel. The control panel contains adjustments and meters for the welding voltage and current and operating switches for rod inching, reversing, travel, and welding current.

The circuit of the series control is shown in Figure 4. If the leads connected across the welding zone are followed through the control circuit, it will be seen that they are connected directly to the rod-feed motor through a rheostat. Since the motor is supplied by the arc voltage, any increase or decrease of this voltage will result in a corresponding change of rod-feed rate. By adjusting the series rheostat, any desired welding voltage will be maintained. This comprises the basic control system, although a few additional components are required. An overvoltage relay is included in the circuit to prevent the low-voltage motor from being subjected to the high open-circuit voltage. A small transformer for rod inching and a reversing switch are also included. For welding with alternating current a variable transformer is substituted for the rheostat.

From the first impression, it would seem probable that the series control, having a high-speed universal motor and series resistance, would give the poorest regulation and stability. In actual practice, however, this is not so, because the load on the motor is practically constant for any one size of rod or speed, and the small variations in load are not sufficient to affect the weld.

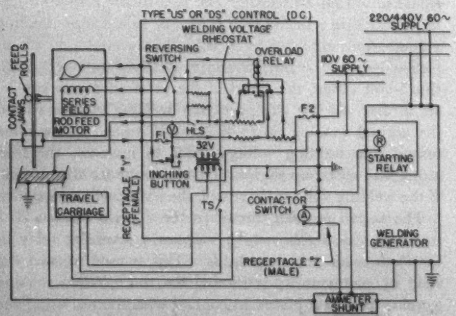

Figure 4. The circuit diagram for series control shows that the leads across the welding zone are connected directly to the rod-feed motor through a rheostat

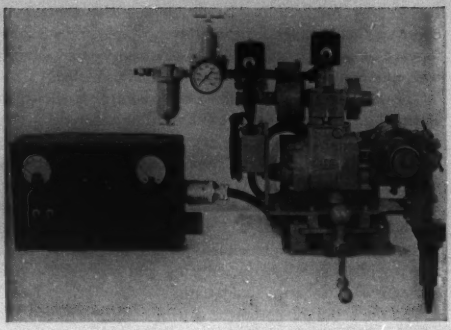

Figure 5. Air-powered welding head and voltage control

During war time, Unionmelt welding is used to a great extent in shipbuilding. For this work it seemed desirable to have a small, rugged, portable welding machine that could be easily serviced by a relatively untrained mechanic. Since compressed-air tools are used extensively in shipyards, the idea of a compressed-air-powered welding machine appealed to many shipbuilders. Therefore, such machines were developed as portable models. Demands for stationary mounting for other types of work have led to the development of the air head and control box as shown in Figure 5.

The actual voltage control consists of a special solenoid valve, which can be seen mounted on top of a 2-horsepower vane-type air motor. Air is introduced into the system through an air cleaner, pressure regulator, and lubricator to a slide valve. The slide valve is actuated by a diaphragm regulator which in turn is controlled by a small needle valve attached to the solenoid armature. The coil of the solenoid is connected across the welding zone and is so designed that a change in welding voltage will result in a corresponding change in the air supplied to the motor.

It was previously pointed out that a welding-voltage control should not be so sensitive as to be affected by the extremely rapid variations in arc voltage. In the three controls just described, this condition is satisfied in different ways. With the electronic control, the rectified voltage from the arc is filtered by means of a choke coil and capacitor which suppresses the unwanted variations before the voltage is applied to the grids of the feed-motor thyratron tubes. In addition, the inertia of the motor armature helps to prevent any sudden speed changes.

With the series control, the motor is supplied directly from the arc voltage. Since it is a high-speed series-type motor, it does not respond to rapid voltage fluctuations. The air head, on the other hand, has a motor which is extremely responsive to input pressure, and if the arc-voltage variations were duplicated exactly by air-pressure variations, the action of the feed motor would be extremely erratic. Consequently, the air control was designed so that the solenoid and mechanical parts of the valve will give a sufficient time lag to average out the arc-voltage variations as in the other control systems.

Loss and Recovery of Synchronism of Parallel Alternators

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When the excitation of one generator of a pair operated in parallel was weakened excessively, the speed of the generator increased to 64 cycles per second. The changes in voltages, currents, and magnetic fields as this situation was remedied are described in this article.

THIS CASE OF operating trouble is both interesting and instructive from a generating station point of view because the graphic record of the electric energy disturbance is complete. The description deals specifically with the in-step and out-of-step relationships of the generator rotor poles to the rotating magnetic poles produced by currents flowing in the stator windings during normal conditions and during the abnormal condition brought about by underexcitation.

While there is nothing unusual about the behavior of the turbogenerator in this case of trouble, as it coincided with known behavior, it is one of those rare cases in which the disturbance, resulting from subnormal excitation of a loaded generator, was recorded from start to finish as shown by the chart in Figure 1.

A tandem compound turbine unit operating at about 90 per cent load, connected only to a 132-kv system, was the setup involved in the trouble. A switchboard operating error resulted in the generator field being excessively weakened, but not opened, during an intended normal regulating operation. This operation consumed only 5 to 8 seconds, after which the kilowatt load on the unit was observed to swing violently, the voltage dropped quite low, and the incandescent lights were observed to pulsate for a few seconds and then, by the strengthening of the field and the decrease of steam input to the turbine by governor action, the disturbance ceased and conditions became normal. The machine had broken step with the system and, while still connected to it, had dropped a large part of its load, accelerated, shut off some of the steam supply, decelerated, and resumed parallel operation, all in about 15 seconds.

To explain exactly what takes place in the parallel operation of generators, it is necessary to state precisely the particular condition that is to be described. Actually what is observed on switchboard instruments is a blending of the results of two principal and distinct influences; these are relative excitation and relative energy input to the generators.

It is necessary, therefore, to keep in mind the particular basic point under discussion as the machine performance under a definite condition is presented step by step. The case in mind here is the behavior of a loaded generator, operating in parallel with others, when its excitation is first decreased below normal and then re-established at its normal value. One way of presenting the case for analysis is to assume a simple bus setup that includes only essential points. This hypothetical generating station has one bus and two generators, and the generators are shut down and the bus is dead. The generators have two poles and the armatures have only one coil per phase (Figures 2 and 3). The armature resistance may be neglected since it is comparatively small in large machines.

One generator is brought up to speed, excited, and connected to the bus. To establish a reference point it may be assumed that the center point on the north pole is under *A*-phase armature conductor at the instant Number 1 generator is put on the bus and before it is given any load, and the steam input to the turbine is maintained to keep the unit at exactly synchronous speed. The dots and arrows of Figure 3 show the instantaneous polarity of the generated voltage, that in *A*-phase being at a maximum for the instant shown. A current in phase with the generated voltage and flowing in the *A*-phase armature coil

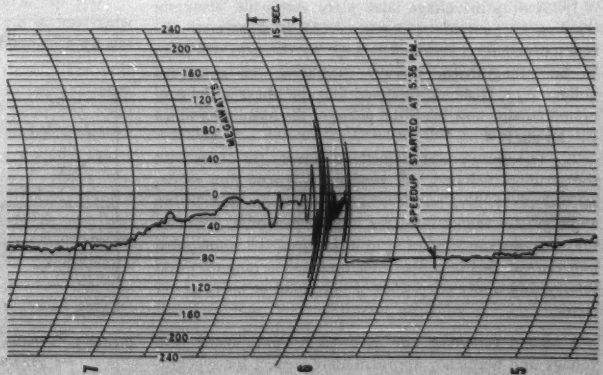

Figure 1. Megawatt output of an a-c generator during a period of subnormal excitation

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will produce a magnetic flux in a plane parallel with the axis of the coil and lagging the axis of the rotor flux by 90 degrees as shown in Figure 3. The relative position of the stator rotating field will be greater or less than 90 degrees depending upon the angle by which the current leads or lags the generated voltage. The generator then is given

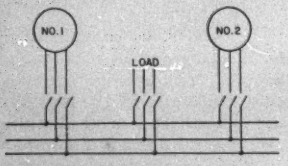

Figure 2. Connections of an elementary generating station

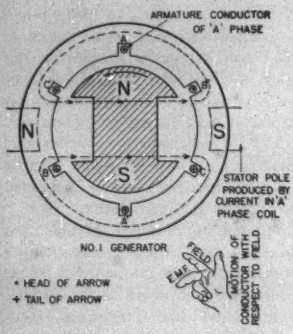

Figure 3. Elementary diagram of a 2-pole 3-phase a-c generator having one slot per pole and phase

a very small load of unity power factor while the steam input is increased so that there is no momentary loss of speed. As the load is put on, there are two important things that occur:

1. A drop in voltage takes place within the armature winding because of its reactance, IX in Figure 4. To maintain constant terminal voltage E_T, the field will have to be strengthened, thereby increasing the generated voltage E_G. It should be noted that the phase of the generated voltage now leads the phase of the terminal voltage by the angle δ.

2. The unity-power-factor load current (in phase with the terminal voltage) will produce magnetic flux as described previously, but it will lag the rotor flux by an angle greater than 90 degrees. In other words, it can be said that the stator poles form in between the rotor poles, and the two sets of poles, rotor and stator, maintain that relationship under conditions of light load at unity power factor.

A second generator now is brought up to speed with voltage and frequency approximately correct for synchronizing. Before synchronizing the second generator, the conditions that exist at the terminals of the switch to be used must be examined. The incoming generator is assumed running at a slightly greater speed than the generator on the bus and the two voltage waves are plotted in Figure 5*A*. The difference in voltage of the two waves, which is the voltage appearing across the open switch of Figure 5*C* and measured by the voltmeter, is shown in Figure 5*B* and can be called the resultant voltage. It is this resultant voltage that is impressed upon synchronizing lamps and synchroscopes. When the speed, and, therefore, the frequency of the incoming generator is adjusted so that the waves of Figure 5*A* coincide exactly, and the voltage of the machine and bus are equal, the proper synchronizing point has been reached and the switch may be closed. At this time the resultant voltage is zero. From here on the operation of the generator is controlled in two ways—by the amount of energy delivered to the drive shaft and by the strength of the rotor poles.

Any momentary slight change in the speed of either generator causes one generator to be ahead of the other, which causes a difference in the time-phase relation of the two instantaneous voltages. The resultant voltage now is impressed upon the series circuit consisting of the two armatures, the bus bars, and the connecting cables. Because of the highly inductive nature of this circuit the current that flows, usually called synchronizing current, lags the resultant voltage by nearly 90 degrees. The phase relationship of the circulating current to the load current in the fast generator will make the two currents additive and, in combination with the generated voltage of that generator, produces a true power load in addition to the load already on that generator, and this slows the generator down.

This load is merely a stiffening of the stator poles which imposes more opposition to the relative forward movement of the rotor poles. Similarly, the phase relation of this circulating current to the load current of the slow generator makes them subtractive, decreases the total current, which decreases the load on the slow generator, decreases the opposition to the forward relative movement of the rotor poles, and allows this rotor to advance.

Thus the action of the circulating current, produced when one of the generators attempts to pull out of step, sets up a reaction which slows down the fast machine and

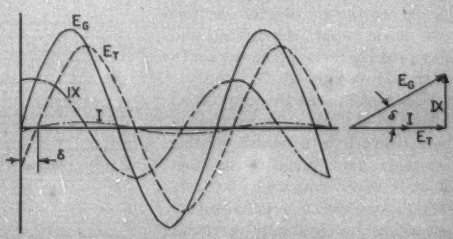

Figure 4. Relation of generated voltage to terminal voltage of an a-c generator with a unity power factor load

E_G = *generated voltage;* E_T = *terminal voltage;* I = *armature current;* δ = *power factor angle*

accelerates the slow machine, thereby tending to keep them in synchronism.

With two generators in parallel, carrying the same load and at the same power factor, it can be assumed that the generated voltage of each machine will lead the terminal voltage by a definite power angle. If the field current of one generator is increased now, the strengthened rotor field will tend to slow the generator down and the power angle will be reduced, as shown in Figure 6. A change in power angle will result in the armature current becoming more lagging since the real power, as supplied by the prime mover, is unchanged. To maintain the bus voltage at a constant value, the excitation to the other machine must be reduced. The weakened rotor field of the second generator will allow it to advance slightly so that its power angle will increase. The effect of this shift is to make the armature current of the machine less lagging. Since regulation of the field current of a machine affects only the quadrature component of armature current, it allows the reactive power of the machine to be controlled. It is significant to note that the power angle, the angle between generated voltage and terminal voltage, is increased when the field is weakened. The power angle is also dependent upon the power supplied the generator shaft by the prime mover.

Load or torque on a turbine is the effort required to push and pull the rotor poles from the position in which the rotating stator poles are trying to hold them. The pole polarities and position relationships tend to pull the south rotor poles away from the north stator poles and force them against the south stator poles when energy is applied to the generator shaft. The more energy supplied to the generator shaft, the greater is the angle of advance of the rotor with respect to its position at no load. As was pointed out previously, a reduction in field excitation also will increase the power angle; this has the same relative effect as increasing the amount of energy supplied the generator shaft. Therefore, both the governor control and the field excitation control produce an effect upon the rotor position relative to the stator poles. When these controls are set so that the south rotor poles are directly under the south stator poles, a critical point has been reached and a further increase in rotor angle will result in the machine falling out of synchronism and it will slip poles.

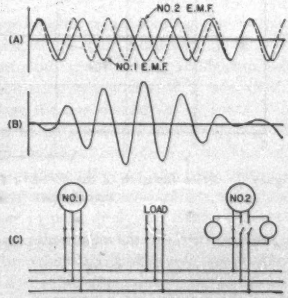

Figure 5. (A) Voltage waves of two a-c generators before synchronizing. Generator Number 2 running faster than generator Number 1. (B) Resultant voltage of two voltage waves shown in (A). (C) Connections of voltmeter or synchroscope upon which the resultant voltage in (B) will be impressed

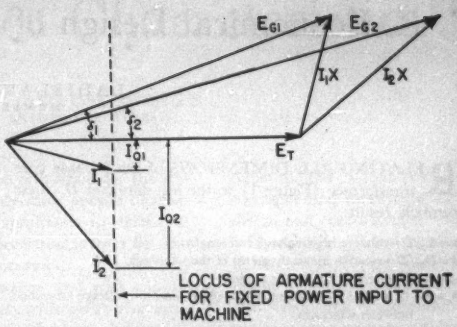

Figure 6. Change in power angle (δ) due to change in field excitation, power input from the turbine remaining constant

Another way of visualizing this critical point is to note that the generated voltage will lead the terminal voltage by a power angle of 90 degrees. For this power angle, the synchronizing power is practically zero so that any slight disturbance will have a tendency to cause instability in the system.

The magnitude of the synchronizing power is dependent upon several factors, two of which are under the operator's control. These are the excitation of the machine and the power angle control achieved by the governor. The greater the excitation, the larger is the synchronizing power. However, a large power angle results in a smaller synchronizing power. It is evident, therefore, that operation of a machine at high load with a relatively weak field sets up a condition where the machine may more easily fall out of step than if operated at a lower load with a strong field.

In this particular case of trouble the machine was connected to the far end of a fairly long transmission line so that the power angle was somewhat greater than it would have been had the generator been feeding the system directly. When the switchboard operator inadvertently weakened the field, the synchronizing power became so low that the generator fell out of step with the system. This generator was driven up to 64 cycles, and as the north rotor poles were driven past the north stator poles, resulting in minimum voltage, the incandescent lights were seen to pulsate at a frequency equal to the difference between the machine and system frequencies, that is, four cycles per second.

When the turbine accelerated, the speed-governing devices reduced the steam input to the turbine allowing it to decelerate. The switchboard operator, diagnosing the situation at this time, strengthened the field, which, with the reduced input of steam and deceleration of the unit, caused the synchronizing power to become great enough to restore the machine to synchronous operation, whereupon it assumed a steady load.

The whole disturbance lasted only 15 seconds. The megawatt chart of Figure 1 shows the interchange of power between the generator and the large system to which it was connected.

Economical Design of a 3-Phase Transformer

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RELATING ALL DIMENSIONS of the 3-phase core transformer (Figure 1) to the leg diameter D, these symbols result:

$\lambda = L_w/D$ = relative high-voltage coil length
$\delta = D_m/D$ = relative mean diameter of the windings
$\alpha = S_c/D^2$ where S_c = net core section
$b_z = \delta + (a_1 + a_2)/3$ = equivalent high-voltage and low-voltage clearance between windings
e_z = per cent full-load reactance voltage

For a transformer of a given output P, frequency f, and voltage ratio U_1/U_2, the core loss P_{Fe}, copper loss P_{Cu}, and impedance voltage e_z are usually prescribed by the standards or set by economical considerations. Because core and windings of the transformer can be subdivided to provide for necessary cooling ducts and surfaces, preliminary design can be performed regardless of cooling requirements.

Expressing both core and copper weight in terms of λ, the variable part of the transformer price

$$C_v = Q_{Fe} + (p_{Cu}/p_{Fe})Q_{Cu} = f(\lambda)$$

Differentiating with respect to λ and setting the result equal to zero will determine λ for lowest possible transformer price. The solution is practically useless because it gives, with regular grade of laminations, a transformer having very high no-load current.

It is therefore necessary to prescribe a value of no-load current I_0 in addition to P_{Fe}, P_{Cu}, and $e_z I_0$ together with P_{Fe}, determined under the assumption of equal leg and yoke density ratio of $v_B/w_B = PI_0/100P_{Fe}$. In this relationship, v_B is the reactive and w_B the active power input to magnetize a unit weight of laminations to the maximum flux density B at a given frequency. The function $B = f(v_B/w_B)$ traced for various steel grades determines only density B conforming to both P_{Fe} and I_0 requirements. The core weight $Q_{Fe} = P_{Fe}/w_B$.

Transformer dimensions conforming to P_{Fe}, P_{Cu}, e_z, and I_0 are governed by the equation

$$\lambda = (3\lambda + 4M/D + 6d/D + 1.5)^{4/3} A$$

where the transformer constant

$$A = \frac{6.3 \times 10^4 P b_z \delta}{\alpha^{2/3} Q_{Fe}^{4/3} f e_z B^2}$$

The most economical design is then derived by varying yoke density and thus changing I_0 within allowances with other performance data unchanged. A new relation $C_v = f(\lambda)$ can be established which will give the lowest priced transformer by finding the minimum of the function.

For the design it is more convenient to plot the variable part of the price C_v against λ (Figure 2). The flat minimum of the chart allows further refinements of the design. With increasing ratio of unit prices of copper and core p_{Cu}/p_{Fe}, minimum price slides to lower λ values.

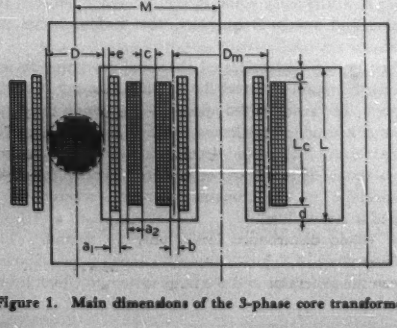

Figure 1. Main dimensions of the 3-phase core transformer

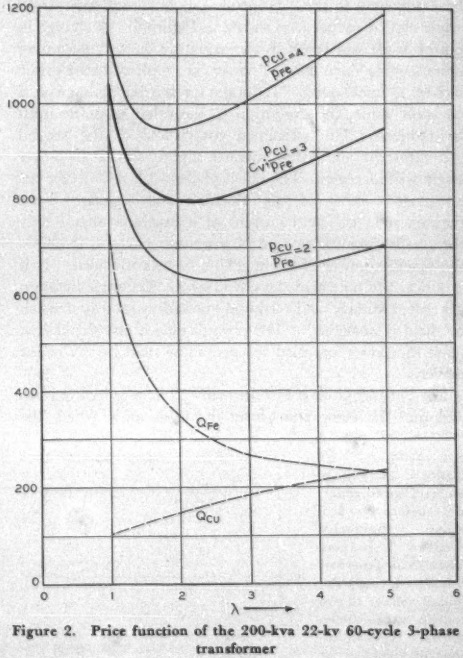

Figure 2. Price function of the 200-kva 22-kv 60-cycle 3-phase transformer

Digest of paper 50-216, "Economical Design of a 3-Phase Transformer," recommended by the AIEE Committee on Transformers and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23-27, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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Magnetic Amplifier Characteristics

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Dimensionless curves are presented for the determination of the steady-state output characteristics of magnetic amplifiers in terms of design parameters. Correction factors for the feedback ratio are calculated. Results obtained by this method agree well with experimental tests for amplifiers with cores of gradually varying incremental permeability.

IN A RECENT STUDY[1] an analysis has been presented for the determination of the steady-state characteristics of magnetic amplifiers in terms of data of design. The method is to apply Kirchhoff's and Faraday's laws to the electric circuits of the amplifier and to use Ampere's law to relate the magnetic field intensities and currents, expressing the empirical relationship between field intensities and flux densities by means of some convenient analytical expressions.

The procedure is facilitated by the use of simplifying assumptions: leakage fluxes, hysteresis, and eddy currents are neglected. The core fluxes are assumed to vary sinusoidally in time. Rectifiers as used in feedback amplifiers are assumed to have infinite resistance in the reverse direction and a constant small resistance in the forward direction.

The method outlined yields expressions for the currents in the various circuits of the basic amplifiers of Figure 1 in the form of harmonic series whose coefficients are functions of the alternating component B_{max} and of the direct component B_0 of the flux density in the cores.

The use of the functional approximation $H=U \sinh uB$ (where H is the field intensity, B is the flux density, and U and u are constants depending on the core material) allows in particular for a simple dimensionless treatment of a most general nature in pure analytical form. For core materials such as hypernik, hypersil, and similar improved transformer alloys, for which the simplifying assumptions already mentioned are valid, the analysis agrees closely with experimental checks within the range of accuracy expected in problems of this nature. This will be seen to be the case even for feedback amplifiers in which elusive phenomena of commutation (that is, simultaneous conduction of all feedback rectifiers) occur in appreciable portions of the cycle and result in apparent increase of the feedback ratio.

DIMENSIONLESS CURVES

THE RESULTS are presented in the form of general dimensionless characteristics that can be used directly for the amplifiers of Figure 1 without need for calculations, other than the simple ones required to convert the dimensionless data to the actual values corresponding to any specific design and core material.

The full line curves illustrated in Figure 2, represent in general dimensionless form the relationship between the alternating voltage across the amplifier terminals and the rectified average value of load current for different values of the total time average magnetomotive force due to signal, bias, and feedback currents for any of the amplifiers of Figure 1.

The dimensionless ordinates

$$\mathfrak{G}_m = uB_{max} = u\frac{E_m}{N}\frac{1}{\omega A} \tag{1}$$

where B_{max} (for example, in webers per square meter)

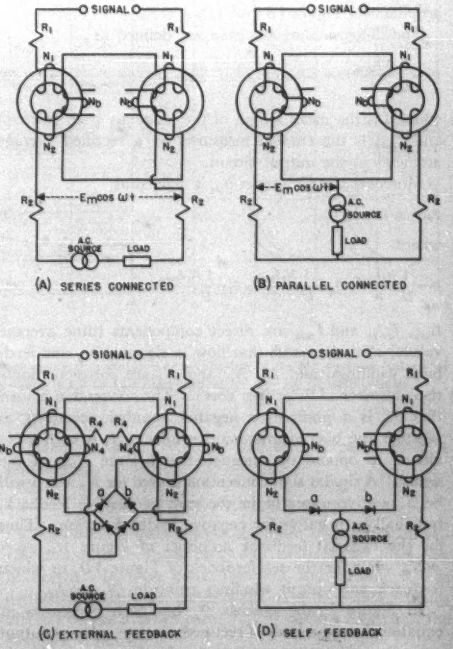

Figure 1. Typical magnetic amplifiers

Essential text of paper 50-148, "General Characteristics of Magnetic Amplifiers," recommended by the AIEE Committee on Electronics and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer and Pacific General Meeting, Pasadena, Calif., June 12-16, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

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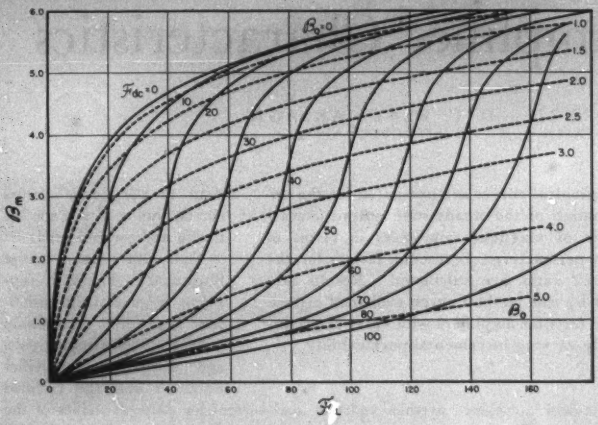


Figure 2. General dimensionless output characteristics of magnetic amplifiers

is the crest of the component of the flux density in the core alternating at frequency f (cycles per second), E_m/N is the crest value of the corresponding volts per turn, $\omega=2\pi f$, and A is the cross-sectional area of one core (square meters). (For the amplifiers of Figures 1*A* and 1*C*, $N=2N_2$; for the amplifiers of Figure 1*B* and 1*D*, $N=N_2$.)

The dimensionless abscissae are defined as

$$\mathfrak{F}_L=\frac{1}{U}\frac{NI_{Lavg}}{l} \tag{2}$$

where l is the mean length of the magnetic path (meters) and I_{Lavg} is the current measured by a rectified average ammeter in the output circuit.

Moreover the parameter $\mathfrak{F}_{dc}$ is defined as

$$\mathfrak{F}_{dc}=\mathfrak{F}_1+\mathfrak{F}_b+\mathfrak{F}_f \tag{3}$$

where

$$\mathfrak{F}_1=\frac{1}{U}\frac{N_1I_{1avg}}{l},\quad \mathfrak{F}_b=\frac{1}{U}\frac{N_bI_{bavg}}{l},\quad \mathfrak{F}_f=\frac{1}{U}\frac{N_fI_{favg}}{l} \tag{4}$$

I_{1avg}, I_{bavg}, and I_{favg} are direct components (time average values) of the currents that flow in signal, bias, and feedback windings, and N_1, N_b, and N_f are correspondingly their number of turns (per core). The convention is used that N_b is a positive or negative number according to whether the bias magnetomotive force N_bI_b is such as to aid or to oppose the magnetomotive force N_{1avg} of the signal. A similar sign convention is used for N_f which will be a positive quantity in the case of positive feedback, but shall be negative for negative feedback action. Thus for the external feedback amplifier of Figure 1*C*, $N_f=\pm N_2$, while for the self-feedback of Figure 1*D*, in which feedback and output windings coincide, $N_f=\pm N_2$.

In Figure 2, the abscissa $\mathfrak{F}_L$ has been chosen as in equation 2 on the basis of rectified average value of output currents as the curves convey in this form more directly usable information on the performance of feedback amplifiers, as shown later. Similar dimensionless curves in terms of rms or of peak output currents could be plotted.

The dotted curves of Figure 2 represent in general dimensionless form the same relationship between $\mathfrak{B}_m$ and $\mathfrak{F}_L$ for different values of the parameter $\mathfrak{B}_0=uB_0$, where B_0 is the direct component of core flux density. These curves convey useful information for the study of commutation phenomena or in the analysis of transients, in which the growth or decay of the direct component of the average core flux is essential, as indicated, for example, in reference 2. The representation of Figure 2 evidences also that $\mathfrak{B}_0$ depends not only on $\mathfrak{F}_{dc}$ but that it depends on $\mathfrak{B}_m$ as well.

By crossplotting the full line curves of Figure 2, Figure 3 is obtained in which $\mathfrak{F}_L$ is plotted as function of $\mathfrak{F}_{dc}$ for various values of $\mathfrak{B}_m$. The curves show the limitations of the so-called turns ratio law. This law states an approximate equality of ampere turns per core of rectified average output currents and of average ampere turns per core of signal, bias, and feedback current; that is, in our notation $(1/2)\mathfrak{F}_L=\mathfrak{F}_{dc}$. It is seen actually that for high enough values of $\mathfrak{F}_{dc}$ these curves are nearly straight lines, whose slopes, however, vary for different values of $\mathfrak{B}_m$. In other terms, the turns ratio law, obtained on the assumption of

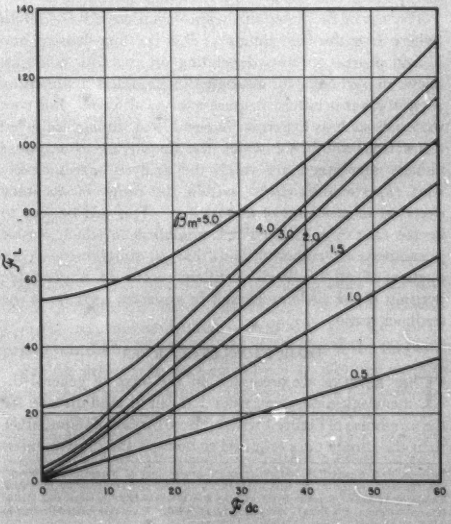


Figure 3. General dimensionless transfer characteristics of magnetic amplifiers

so-called square magnetization curves, may not apply too well to materials with gradually varying incremental permeability with which this analysis is concerned.

AMPLIFIERS WITHOUT FEEDBACK

THE FULL LINE CURVES of Figure 2 allow the immediate evaluation of the operating point of any amplifier without feedback (Figures 1*A* and 1*B*, for which $N_f=0$), for any specific instance for which data of design (resistance, number of turns of the various windings, core cross section, and mean length) and magnetization curve of the material (expressed in terms of the parameters U and u) and signal and bias currents and alternating voltage across the output windings are given.

Load lines expressing the possible points of operation of a magnetic amplifier for various values of signal current and fixed a-c supply voltage and load also can be plotted in dimensionless form on the chart of Figure 2. For instance, the known elliptical load lines that result for a resistive load R_L under the approximate assumption of sinusoidal output current can be represented on the chart also with ellipses whose axes coincide with the co-ordinate axes. The intercept $\mathfrak{G}_{mi}$ of such ellipses with the ordinate axis is the value of $\mathfrak{G}_m$ corresponding to zero output current (infinite reactance of the output windings). Thus, if the supply voltage is V_{rms}, it follows from equation 1

$$\mathfrak{G}_{mi}=u\frac{\sqrt{2}V_{rms}}{N}\frac{1}{\omega A} \tag{5}$$

On the other hand, the intercept with the abscissae axis is

$$\mathfrak{F}_{Li}=\mathfrak{G}_{mi}/\mathfrak{R} \tag{6}$$

where

$$\mathfrak{R}=uU\frac{\pi}{2}\frac{l}{N^2\omega A}R \tag{7}$$

If R_2 is the resistance of winding N_2, then $R=R_L+2R_2$ for the amplifier shown in Figure 1*A* and $R=R_L+1/2\,R_2$ for the amplifier shown in Figure 1*B*. More general elliptical loci that result for nonrectified loads consisting of resistance and inductance, or the straight lines into which the loci degenerate for the case of purely inductive loads, and negligible power winding resistance R_2 can be plotted on the chart of Figure 2 for any specific instance of given a-c supply voltages and load impedances in a similar way.

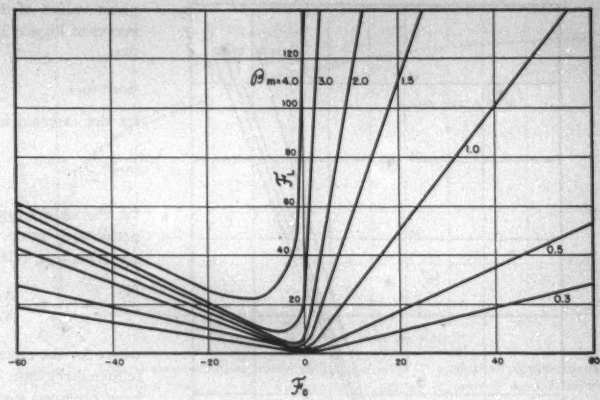


Figure 4. Dimensionless transfer characteristics for magnetic amplifiers with feedback negligible commutation, and feedback ratio $N_f/N_2=1.0$ for various values of $\mathfrak{G}_m$

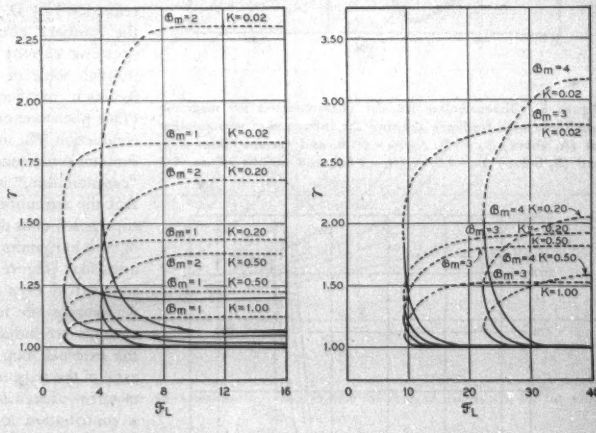


Figure 5. The feedback correction factor γ as a function of $\mathfrak{F}_L$ for various values of $\mathfrak{G}_m$ and k for $N_f/N_2=+1.0$ in full lines and $N_f/N_2=-1.0$ in dotted lines

AMPLIFIERS WITH FEEDBACK

THE DIMENSIONLESS CURVES of Figure 2 apply for amplifiers with feedback also, and similar load lines can be drawn. In these cases, however, the variable $\mathfrak{F}_{do}$, as defined in equation 3, includes the term $\mathfrak{F}_f$, which depends directly on the average value I_{fav_g} of current flowing in the feedback windings.

Transfer curves, expressing $\mathfrak{F}_L$ as function of the dimensionless control magnetomotive force $\mathfrak{F}_c=\mathfrak{F}_1+\mathfrak{F}_f$ for

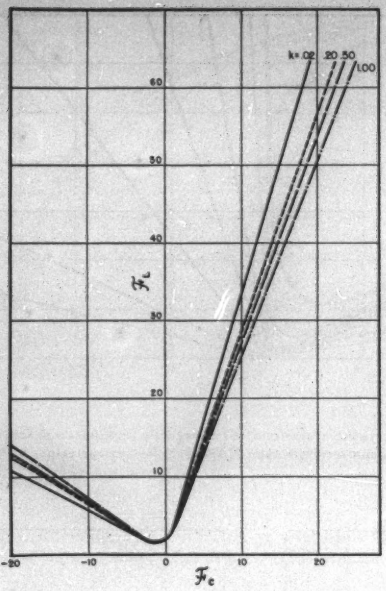
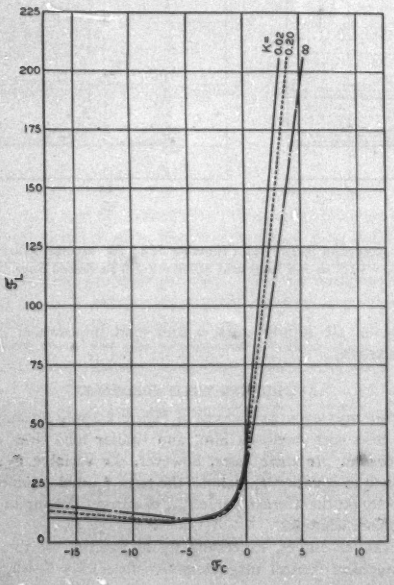


Figure 6. Dimensionless transfer characteristics for magnetic amplifiers with feedback showing the influence of commutation for (A, above) $\mathfrak{G}_m=1.0$, $N_f/N_3=+1.0$, and various values of k, and (B, below) $\mathfrak{G}_m=3.0$, $N_f/N_3=+1.0$, and various values of k



given values of $\mathfrak{G}_m$, are obtained immediately from the curves of Figure 3, whenever the assumption can be made that

$$I_{fave}=I_{Lave} \tag{8}$$

for the external feedback amplifier, and

$$I_{fave}=\frac{1}{2}I_{Lave}$$

for the self-feedback amplifier. The dimensionless magnetomotive force $\mathfrak{F}_C$ of the control windings (bias and signal) is then related to $\mathfrak{F}_{de}$ by

$$\mathfrak{F}_C=\mathfrak{F}_1+\mathfrak{F}_b=\mathfrak{F}_{de}-\frac{N_f}{N_3}\frac{1}{2}\mathfrak{F}_L \tag{9}$$

where for the external feedback case $N_f=\pm N_4$ and for the self-feedback case $N_f=\pm N_3$. The curves of Figure 4 have been obtained under the assumption given in equation 8 for a feedback ratio $N_f/N_3=1$.

Conditions may arise, however, for which I_{fave} is greater than the value given in equation 8. This phenomenon has been recognized already in the early papers of T. Buchhold,[3] and has been mentioned also in a discussion of reference 4 by D. B. Corbyn. In the wording of Corbyn, the feedback circuit is highly inductive and, hence, a decaying current may be expected to continue flowing through some of the feedback rectifiers when the other feedback rectifiers have already initiated conduction. (This phenomenon is not to be confused with the reverse conduction that may be due to imperfect rectifiers.) This simultaneous conduction of all feedback rectifiers, or "commutation," is explained in the analysis[1] considering that the assumption of a sinusoidally alternating core flux superposed on a direct component of flux implies the need of even harmonics of magnetomotive forces. In the simple amplifier (Figure 1*A*) these magnetomotive forces are supplied by even harmonic currents flowing in the signal windings, while for the amplifier (Figure 1*B*), harmonic currents are induced in the signal windings as well as in the external loop of the output windings in the inverse ratio of the resistance and in the direct ratio of the number of turns. Likewise for the amplifiers (Figures 1*C* and 1*D*) a contribution to the total need of even harmonics of magnetomotive force should be expected to be provided by current flowing in the feedback windings, this contribution being dictated by ratios of resistances and numbers of turns and being not necessarily coincident with the even harmonics which result simply from the rectification of the currents supplied by the a-c source.

The detailed analysis established in reference 1 does not need to be repeated here. It appears practical to account for effects of commutation simply by means of a convenient correction factor γ applied to the feedback ratio. With the introduction of this factor, equation 9 is modified into the more general one

$$\mathfrak{F}_C=\mathfrak{F}_1+\mathfrak{F}_b=\mathfrak{F}_{de}-\gamma\frac{N_f}{N_3}\frac{1}{2}\mathfrak{F}_L \tag{10}$$

which no longer requires the not always acceptable as-

sumption $I_{Ave}=I_{Lave}$ or $(1/2)I_{Lave}$ as indicated in equation 8.

The factor γ depends on $\mathfrak{G}_0$ and $\mathfrak{G}_m$ and on the number of turns of the signal, bias, and feedback windings and the resistance of their circuits. It also can be expressed in terms of $\mathfrak{G}_m$, $\mathfrak{F}_L$, and of a further factor k, defined as

$$k=\left(\frac{N_1}{N_f}\right)^2\left(\frac{R_f}{R_C}\right) \tag{11}$$

R_f is the resistance of the feedback circuits during commutation; $R_f=2R_4+R_r$ for the external feedback amplifier, and $R_f=2R_2+2R_r$ for the self-feedback amplifier, where R_r is the forward resistance of one rectifier arm. R_C is the resistance of the combined signal and bias circuits as given by

$$\frac{1}{R_C}=\frac{1}{2R_1}+\left(\frac{N_b}{N_1}\right)^2\left(\frac{1}{2R_b}\right) \tag{12}$$

where $2R_1$ and $2R_b$ are the resistances of the signal and bias circuits respectively. Thus in the case of no bias windings

$$k=\left(\frac{N_1}{N_4}\right)^2\left(\frac{2R_4+R_r}{2R_1}\right)$$

for the external feedback amplifier, and

$$k=\left(\frac{N_1}{N_2}\right)^2\left(\frac{R_2+R_r}{R_1}\right)$$

for the self-feedback amplifier circuit.

Figure 5 shows values of γ as a function of $\mathfrak{F}_L$ for fixed values of k and $\mathfrak{G}_m$, assuming $N_f/N_2=\pm 1.0$ (as is the case for self-feedback or for external feedback with 100-per cent feedback ratio). It is seen that γ is very close to unity when k is large, that is, when signal or bias windings offer comparatively easy paths to induced currents satisfying the needs of even harmonics of total magnetomotive force. It is in such cases that the simplifying assumption given in equation 8 can be accepted, that is, commutation phenomena are ignored. On the other hand, small values of k (as they may occur in feedback amplifiers in which forcing resistors are used to improve the speed of response) cause a considerable increase of feedback action.

Figures 6A and 6B indicate transfer characteristics obtained for $\mathfrak{G}_m=1.0$ and $\mathfrak{G}_m=3.0$ and $N_f/N_2\doteq+1.0$, for various values of k. These are found directly from Figures 3 and 5 in the following manner. Knowing the value of $\mathfrak{G}_m$ the appropriate transfer curve of $\mathfrak{F}_L$ versus $\mathfrak{F}_{dc}$ can be found from Figure 3. Then, from the value of k given by equation 11, γ can be found using Figure 5 for the various values of $\mathfrak{F}_L$. $\mathfrak{F}_C$ then is found from equation 10. It is seen again that small values of k may give transfer characteristics which are considerably steeper than the one obtained for the same values of $\mathfrak{G}_m$ in Figure 4 in which commutation was neglected. On the other hand, no appreciable differences are found when k is large ($k\geq 1.0$).

Commutation phenomena are of particular significance, for instance, when the resistance of the signal circuit is increased by means of forcing resistors, which are frequently used to improve the speed of response. For the case of positive feedback, the forcing resistor shifts upon the feedback windings the burden of providing the $\mathfrak{F}_{dc}$ needed for a given output $\mathfrak{F}_L$. That is, as $\mathfrak{F}_f$ increases the need for $\mathfrak{F}_1$ decreases (as shown clearly by the increased slope of

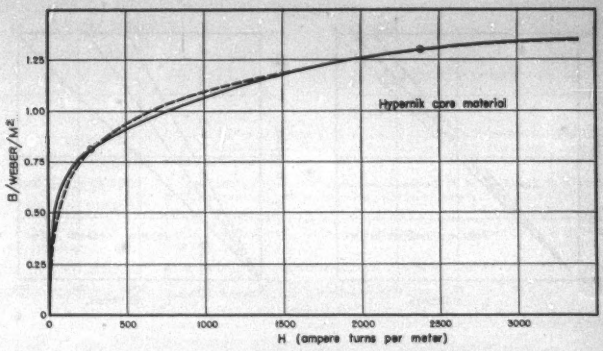


Figure 7. Normal magnetization curve (solid line) and its analytical approximation $H=U\sinh \alpha B$ (dotted line). $U=12.7$ ampere turns per meter, $\alpha=4.6$ square meters per weber

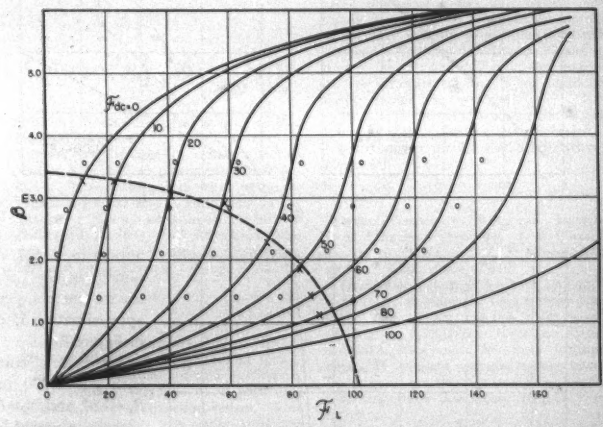


Figure 8. General dimensionless output curves with samples of experimental checks. The circled points check the no-load curves and the crossed points are for the elliptical load line

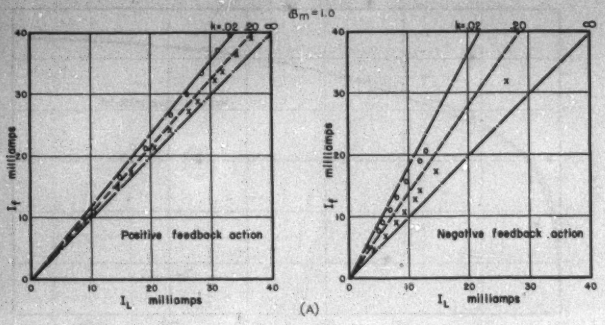


Figure 9 (A and B). Average feedback current as a function of the rectified average load current in the amplifier with feedback showing the effect of resistance of the control circuits on the feedback ratio, for positive and negative feedback action, $N_f/N_3 = \pm 1.0$. The dotted points are for $k = 0.02$ and the crossed for $k = 0.20$. (A) $\mathfrak{G}_m = 1.0$, (B) $\mathfrak{G}_m = 3.0$

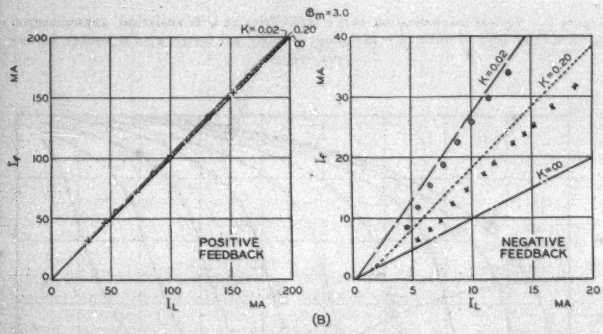
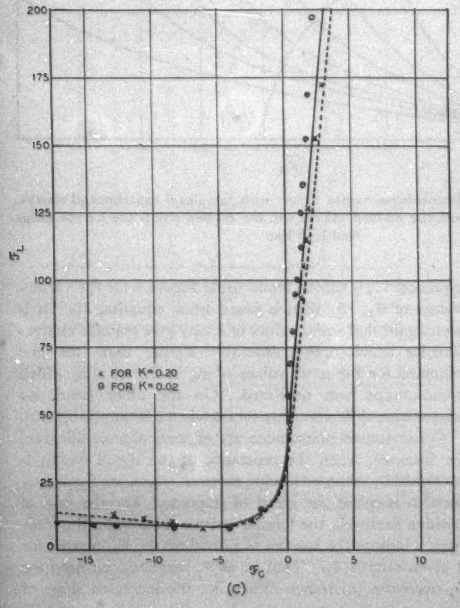


Figure 9 (C). Calculated dimensionless transfer characteristics for $\mathfrak{G}_m = 3.0$, $N_f/N_3 = 1.0$ for $k = 0.20$ (dotted line) and $k = 0.02$ (solid line) showing the influence of commutation with experimental points



the transfer characteristics which are shown in Figure 6).

EXPERIMENTAL CHECKS

Samples of experimental results are given as obtained on amplifiers with the following core specifications: material, hypernik; core area $A = 4.2\ 10^{-4}$ square meter; mean length $l = 0.181$ meter.

The normal magnetization curve, obtained with a moving coil fluxmeter, is shown in Figure 7. In the dimensionless analysis, the magnetic properties of the core are expressed by the two constants U and u of the approximation $H = U \sinh uB$. These constants are obtained as $U = 127$ ampere turns per meter and $u = 4.6$ square meters per weber, and the resulting analytical approximation is compared with the experimental curve in Figure 7.

The basic circuits of Figures 1*A* and 1*B* have been used with $N_1 = 2{,}000$ turns, $R_1 = 100$ ohms, $N_3 = 2{,}000$ turns, $R_3 = 120$, and $N_b = 0$. The rms volts per turn (at 60 cycles) have been varied from 0 to 0.12 and the rectified average output current has been measured for fixed values of average signal current I_1 varying from 0 to 200 milliamperes. A few typical experimental values are converted into dimensionless values as per equations 1 to 4 and then plotted on the dimensionless chart.

An additional sample of experiments on operation with load also is represented in Figure 8. For this the amplifier (Figure 1*A*), with the same winding data as before, has been used with a series load resistance $R_L = 5{,}040$ ohms and with a fixed 60-cycle supply voltage of 338 volts rms. The output currents corresponding to various values of signal, after reduction to dimensionless values, have been marked as crosses in Figure 8, in which also the corresponding theoretical elliptical locus ($\mathfrak{R} = 0.033$, intercepts $\mathfrak{G}_{m1} = 3.40$, $\mathfrak{F}_{L_1} = 102$) is shown.

Figure 9 shows the increase of average value of feedback current resulting from commutation phenomena. For this the external feedback amplifier of Figure 1*C* has been used with the same hypernik cores and following winding

specification: $N_2=2{,}000$ turns, $R_2=120$ ohms, $N_b=20$, $N_f=2{,}000$ turns, $R_f=216$ ohms (including rectifier resistance as given after equation 11). The number of turns in the signal windings has been kept fixed at 500 turns, but using two different values of R_1 equal to 33.7 and 337 ohms so as to give two different values of k equal to 0.20 and 0.02 respectively (as per equation 11). Constant 60-cycle voltages of 98 rms and 294 rms volts (such as to give $\mathfrak{G}_m=1.0$ and $\mathfrak{G}_m=3.0$) were applied at the amplifier output terminals, and simultaneous readings of output current and current in the feedback windings were taken by varying the signal. Figures 9*A* and 9*B* show the comparison of the experiment with theoretical values of the analysis for the two values of k and for positive and negative feedback action. The 45-degree line plotted corresponds to the simplified case of no commutation ($k=\infty$). Figure 9*C* presents experimental checks on the over-all influence of the commutation phenomena upon the transfer curves.

REFERENCES

1. Analytical Determination of Characteristics of Magnetic Amplifiers with Feedback, D. W. VerPlanck, L. A. Finzi, D. C. Beaumariage. AIEE *Transactions*, volume 68, part I, 1949, pages 565–70.

2. An Analysis of Transients in Magnetic Amplifiers, D. W. VerPlanck, L. A. Finzi, D. C. Beaumariage. AIEE *Transactions*, volume 69, part I, 1950, pages 498–503.

3. Uber Gleichstromvormagnetisierte Wechselstromdrosselspulen und Deren Rueckkopplung, T. Buchhold. *Archiv fur Electrotechnik* (Berlin, Germany), volume 36, 1942, page 221.

4. A Theoretical and Experimental Study of the Series-Connected Magnetic Amplifier, H. M. Gale, P. D. Atkinson. *Proceedings*, Institution of Electrical Engineers (London, England), volume 96, part 1, number 99, May 1949.

Digests of Conference Papers Presented at Fall General Meeting

These are authors' digests of most of the conference papers presented at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23-27, 1950. These papers are not scheduled for publication in AIEE Transactions or AIEE Proceedings, nor are they available from the Institute.

The Use of Electricity in Bauxite Mining; *E. A. Brenn (Alcoa Mining Company, New York, N. Y.).*

The use of electricity is an important factor in the processing of bauxite, which is the most important commercial ore of aluminum. Bauxite is found in many parts of the world; the largest mining operations of the Aluminum Company of America are centered in Arkansas and in Suriname, a Dutch colony on the northeast coast of South America. Open-pit methods are used for most of the mining, with a limited amount of underground work being used in the Arkansas mines.

Diesel-powered equipment is commonly used in stripping and mining in the open-pit method, while electric power is extensively used in underground operations. Recently an electric shovel has been added to the open-pit equipment in Suriname, where for several years diesel-electric locomotives have been used in tramming. Electric power is used in all operations for pumps, compressors, lighting, and so forth.

In the milling process, every step, from the unloading of a car of ore until shipment, is powered by electric motors. The process includes steel pan feeders, gyratory and hammermill crushers, belt conveyors, rotary drying kilns, storage buildings, and shipping facilities. Special electrical control devices are used extensively.

Power is purchased in Arkansas but is generated in modern power plants in Suriname. Transmission lines carry power at 13,800 and 2,300 volts to substations in the mining or milling areas from which it is distributed at 480 volts. Aluminum wire and cable is extensively used for transmission lines and for distribution through aluminum conduit in the mills.

Industrial Power Networks; *H. D. Hughes (Stanolind Oil and Gas Company, Tulsa, Okla.).*

This paper describes a unique application of the network principle to a particular industrial power distribution system. This system is the solution to a rather interesting design problem, which was to modify an existing electrical distribution system to fit the requirements of an entirely new and very complex industrial operation.

The installation is the Tulsa Maintenance Depot of American Airlines, Inc., which is the central shop for the entire system. The depot is completely equipped for periodic inspection and repair of all transport planes.

Power was required for many types of machine and hand tools. This equipment was distributed over a large floor space. There was very little available space for load centers or other distribution equipment. The location of all equipment was fairly well defined, but the load characteristics of many pieces of equipment were rather indefinite. These conditions required extra flexibility in the capacity of the distribution system. Voltage regulation presented a problem, and extremely dependable service also was required.

Many of the requirements for this system indicated that a network type of distribution system was required. Some features indicated that plug-in bus duct feeders were highly desirable. All of the design requirements were fulfilled by a 4-unit loop-type network. The bus-tie circuits consist of plug-in bus ducts. All loads are plugged directly into these tie circuits; no additional feeder circuits are required.

In order to make the maximum economical use of existing equipment and machinery, it was necessary to provide both a 120/208-volt and a 480-volt network.

System Frequency Response Derived from Transient Response; *A. R. Teasdale, Jr., F. E. Brooks, Jr., J. P. German (University of Texas, Austin, Tex.).*

In making a study of feedback systems, it is necessary to know the loop transfer function. This transfer function may be derived from calculations based on circuit constants, steady-state frequency measurements, or transient response measurements. The transfer function can be written directly from amplitude and phase frequency response.

It is more desirable to design in terms of frequency response, but these measurements are not always simple. One must contend with system heating, drift, and long strings of data. These problems are not so severe in making transient runs. This paper shows methods of evaluating the frequency response from transient response to a step function, a unit impulse, a doublet impulse, and higher order impulses. Developments are based on the Laplace transformations.

The frequency response $G(j\omega)$ of a system may be obtained from the response $f(t)$ to a unit step function by the following expression:

$$G(i\omega)=\int_0^\infty f'(t)\epsilon^{-j\omega t}dt$$

$$=\sum_{n=1}^{n}\Delta f(t_n)\underline{/\omega t_n}$$

This complex integration may be considered a complex sum of step functions.

The response $G(j\omega)$ of a system may be obtained from the system response $f(t)$ to a

unit first order impulse by the following expression:

$$G(j\omega) = \int_0^\infty f(t)e^{-j\omega t}dt$$

$$= \sum_{n=0}^{\infty} f(t_n/-\omega t_n$$

This complex integration may be considered a complex sum of firs order impulses.

These methods may be extended to give $G(j\omega)$ in terms of the response to higher order unit impulses.

The Torsional Damper for Conductors—Service Experience and Further Experimental Work; *T. J. Burgess, A. D. Hogg (The Hydro-Electric Power Commission of Ontario, Toronto, Ontario, Canada).*

Investigational work on aeolian vibration in transmission conductors initiated about 1930 by The Hydro-Electric Power Commission of Ontario led to the development of an effective articulated torsional damper.

A phase of the continuation of this work of some possible general interest dealt with the effect of tension on vibration in aluminum-cable steel-reinforced (ACSR) conductors from Number 3/0 to 605,000 circular mils in size. The data indicate that at tensions up to about eight per cent of the ultimate strength there is little vibration. From 8 to 15 per cent the maximum bending at the clamp increases rapidly, and then remains constant for further increases in tension. The number of cycles of vibration above any given amplitude, however, increase linearly with tension above the 8-per cent threshold tension.

Recently reported trouble makes information obtained on the type-*HH* 500,000-circular-mil copper conductor of interest. A line with a tension of 20 per cent and spans of 880 feet was found to vibrate naturally at not over one-third the fatigue limit. Thus it has been considered unnecessary to use the rigid torsional dampers developed for this line. Recent careful inspection after nine years of operation showed no trouble.

The torsional damper for ACSR conductors, which is much superior to the rigid damper, has been used extensively up to ten years on several conductor sizes. No trouble has been found by recent careful inspections of (1). a 477,000-circular-mil line with a 60-degree tension of 15 per cent of the ultimate strength and spans of 1,000 feet; and (2). a 795,000-circular-mil line with a 60-degree tension of 19 per cent and spans of 1,150 feet.

Aeolian Vibration—Experience with and Remedial Measures for Failures in Overhead Ground Wires; *R. F. Danner (Oklahoma Gas and Electric Company, Oklahoma City, Okla.).*

In 1948 and 1949, the Oklahoma Gas and Electric Company installed 5/16-inch Extra-High-Strength (EHS) 7-strand steel lightning shield wires on some of its new 66-kv and 138-kv H-frame and steel tower transmission lines to provide the desired mid-span separation between shield wires and conductors at minimum cost. The EHS wire was strung with initial tensions of 23 to 28 per cent of ultimate strength at 60 degrees Fahrenheit. Within five months, breakage of the steel strands at the edge of the suspension clamps began to occur.

It was observed that vibration was severe throughout a wide range of temperature and wind velocities, although there was little or no vibration of shield wires on both new and older transmission lines which had been installed at a tension of 15 per cent of ultimate at 60 degrees Fahrenheit.

After considering various remedial measures, it was decided to (1). repair and strengthen the wire at each of the original points of support by installing preformed 63-inch long armor rods; (2). resag the wire to a tension of 15 per cent of ultimate strength at 60 degrees Fahrenheit; and (3). install these armor rods at the new point of support as an added measure of protection on the lines.

This experience indicates that with tensions as high as 23 to 28 per cent of ultimate, aeolian vibration may be so predominant and so severe in some localities as to cause fatigue failures, and the safe limit may be in the order of 15 per cent. No fatigue failures have occurred on overhead ground lines which were constructed 20 years ago where the shield wires were sagged at 15 per cent of ultimate.

The use of preformed armor rods appears to be one of possibly other economical and satisfactory methods of rehabilitating damaged wire, and for providing a measure of protection from fatigue at the point of support.

Failures of Overhead Ground Wires Caused by Aeolian Vibration; *P. G. Wallace (Texas Power and Light Company, Dallas, Tex.).*

Experience with several types of overhead ground wire installations indicates that the use of rigid or partially restrained supports limits the normal safe operating tension of the cable to less than 15 per cent of its ultimate strength, and this limit should not be exceeded unless measures are taken to reduce the bending stress caused by the vibration at the clamp.

The use of very mobile suspension clamps should permit higher normal operating tensions without necessitating additional antivibratory measures. Indications are that the limitation can be raised to approximately 20 per cent of the ultimate strength.

Experience with preformed armor rods installed on 3/8-inch high-strength steel strand in 1946 and operating at about 18 per cent of ultimate strength indicates that they will definitely reduce vibration fatigue. An inspection of this installation shows no signs of abrasion after four years of service.

Possible damage to supporting structures and their appurtenances caused by aeolian vibration should be considered when designing an overhead ground wire installation. Pole ground wires should be attached to the static wire support rather than connected direct to the shield wire. Use of the single-angle iron crossarm will provide a sufficiently rugged and safe tie between the two shield wires on wooden H-frame lines. In addition, this type of shield wire support lends itself readily to the use of a flexible clamping device.

Progress in Conductor Vibration Investigations; *Joel Tompkins (Aluminum Company of America, Massena, N. Y.).*

Investigations of overhead conductor vibration are being carried on in Massena, N. Y., in an enlarged Electrical Conductor Laboratory operated by the Electrical Engineering Division of Aluminum Research Laboratories of Aluminum Company of America.

Indoor laboratory facilities include a number of 120-foot test spans, with lever-loading systems for control of conductor tension and new electromagnetic vibration-inducing equipment with automatic amplitude control features. Improved methods of conducting vibration fatigue tests of conductors protected with armor rods include the use of very sensitive recording equipment to indicate the failure of a conductor strand under the rods without disturbing the rods.

In addition to the indoor spans, a number of outdoor test spans, from 400 to 1,500 feet in length, are also available at Massena to allow the study of natural wind-induced conductor vibration and to allow direct evaluation of effectiveness of vibration damping devices. Among other results that have been obtained using these spans, it has been found that standard straight and tapered armor rods contribute more vibration damping than had previously been recognized generally. On three sizes of cable, representing a wide range of diameters, armor rods appear to reduce amplitude of vibration by roughly 40 to 50 per cent at fairly low wind velocities, with even greater reductions at higher wind velocities.

BPA Experience with Conductor Vibration; *M. B. Elton, A. A. Osipovich, M. G. Poland (Bonneville Power Administration, Portland, Oreg.).*

During a vibration damper installation on the 100-mile Midway-Grand Coulee 230-kv Line 2 five years after construction, an inspection was made of the 500,000-circular mil expanded high-strength copper conductor. From one to eight of the outer copper strands were found broken within the suspension clamp due to vibration fatigue on 23½ per cent of the 468 towers inspected.

Of the several methods of repair considered, the use of a stainless steel preformed armor rod was finally adopted because of its low magnetic power loss, excellent gripping action, ease of installation, and vibration suppression characteristics.

Bonneville Power Administration (BPA) now is sponsoring vibration laboratory work at Washington State College where tests are proposed on various dampers, armor rods, new types of suspension clamps, and so forth. Conductor stress analyses and fatigue tests also are proposed on the various types of conductors used by BPA. Also stress analyses of the conductor overhead ground wire and steel towers will be made with the use of strain gauges under vibration conditions in the field.

BPA is developing, through the facilities of Oregon State College, an improved type of vibration recorder. This recorder, like present recorders, will be used on energized transmission lines. However, it will be provided with weekly charts rather than daily and will record frequency simul-

taneously with the amplitude without recourse to wind direction and velocity. Another type of hot-line recorder being developed will record the vibration wave shape.

Aeolian Vibration Combines with Galloping to Speed Failures in Conductors; *A. E. Davidson* (*The Hydro-Electric Power Commission of Ontario, Toronto, Ontario, Canada*).

Except for the application of absorbers, reinforcements, and other types of suppression, there is, as yet, no recognized solution for the destructive effects of both aeolian vibration and galloping, under glaze loads, to the material; these effects frequently make transmission lines inoperative.

Theoretically, it could be assumed that aeolian vibration, over long periods, breaks one or more strands of a cable at or near the top or bottom of a conductor in its normal position. If these glassy fractures are found at the top and bottom of a fracture and if they are interspersed through the balance of the strands of a conducting cable, then it can be assumed that both types of fatiguing and stress had, at one time or another, worked on the cable at its weakest point.

The Use of IBM Punched Card Devices for Distillation Calculations; *Arthur Rose, Theodore J. Williams* (*The Pennsylvania State College, State College, Pa.*).

A distillation column or tower is made up of a number of discrete units or plates, each containing a limited amount of liquid. Each plate receives vapor from the plate below and discharges vapor of somewhat different composition to the plate above. Simultaneously, liquid is received from the plate above, and other liquid overflows to the plate below. A basic computational problem is to obtain the compositions at a given point in the column when composition at some other point is known and when values also are known for the rates of flow and the characteristics of the liquid mixture and of the devices for mixing liquid and vapor on the plate.

The process is most laborious when many plates (50 to 100) are involved, since equations then must be used as many times as there are plates, or the graphical procedure must be carried through an equivalent number of steps. Often circumstances require repetition of the process as part of a larger trial and error solution.

Automatic digital computers are admirably suited to these calculations, since cumulative errors are held to very small values, human errors are eliminated, high speeds of calculation are achieved, and all circumstances can be taken into account.

Current Loadings for ACSR Conductors; *A. S. Runciman* (*The Shawinigan Water and Power Company, Montreal, Quebec, Canada*).

On occasion it has been necessary to carry currents which are well above those normally specified and above economic ratings for aluminum-cable steel-reinforced conductors.

Test data have been collected from lines in normal service at high loads and also from special outdoor arrangements. Wind direction and velocity were recorded as well as temperature rise and current.

Temperature rise versus current plotted on a log-log graph form is almost a straight line. The plot of test data shows a displacement depending on air movement to be added to the temperature rise versus current data supplied by cable manufacturers for still air conditions.

Multilayer stranding for one size of conductor made no appreciable difference in temperature rise at high currents.

Line Structures for 66,000 Volts—An Established Subtransmission Voltage in New England; *C. A. Booker* (*New England Power Service Company, Boston, Mass.*).

The early 66,000-volt transmission system in New England has been superseded by higher voltage lines for the transmission of power in bulk. However, the original system now comprising over 700 miles of circuit will remain in service as subtransmission and will be added to as circumstances indicate.

Before 1924 it was most common to erect double circuit steel tower lines with either pin-type or suspension-type insulators. On such lines approximately 60 per cent of all lightning disturbances affect both circuits. The higher voltage transmission system makes it feasible to feed nearly all 66,000-volt lines from both ends which, with proper sectionalizing switches, assures nearly uninterrupted service to all important loads.

During World War I some lines were constructed on wood poles with such satisfactory service results that wood construction is preferred now. A number of new types of lines have been developed to take advantage of the impulse insulating characteristics of such wood.

The "K Frame" is a double-pole double-circuit line having wood crossarms and double purpose braces resembling the letter K face down. This type has been highly satisfactory where two circuits must be carried on one structure.

The "Polarm" is a double-pole single-circuit structure with a wood-pole crossarm. One of the vertical poles is placed at the end of and extended ten feet above the crossarm to carry an elevated aerial ground wire. This type provides lightning protection equivalent to about 15 discs on a steel line.

The "Offset Wood Bayonet" is a single-pole modification of the Polarm principle for application on lines having light conductors. It provides lightning protection equivalent to about ten discs.

Operating Experience with Ground Distance Relays; *M. P. Osborn, P. L. Dandeno* (*The Hydro-Electric Power Commission of Ontario, Toronto, Ontario, Canada*).

Operating experience given by ground distance relays on the 25-cycle system of the Hydro-Electric Power Commission of Ontario is discussed. The period covered in the records presented is for the past 15 years, although this type of relay scheme has been employed for 22 years on the 230-kv 25-cycle system and for 18 years on the 115-kv 25-cycle system.

The 115-kv 25-cycle system is resistance grounded at about six main points on this network; the lack of proximate grounding sources at some of the busses has discriminated against a better record of correct operations than 85 per cent. The 230-kv 25-cycle system record is better than 85-per cent correct operations since this network is solidly grounded; the record for 2-terminal line operation only on the four 230-kv circuits considered showed an average of 95.6-per cent correct relay operations.

The experience gained by the Commission indicates that a definite field of application exists for this type of ground relay protection especially where nonsequential fault clearing can be tolerated and carrier current expense is unwarranted.

A Special Purpose Analogue Computing System for the Radar Triangulation Problem; *R. E. Langworthy, R. M. Byrne* (*Goodyear Aircraft Corporation, Akron, Ohio*).

This computing system employs general purpose analogue computers, as well as a number of special purpose devices, to solve the radar beacon triangulation problem. The computer is designed to accept range information from five radar beacon triangulation stations and to produce automatically a plot of position of an airborne target beacon in rectangular co-ordinates as a function of time and as a function of one of the co-ordinates. In addition, the co-ordinate velocities may be plotted as a function of time.

The basic unit of this computing system is the Goodyear Electronic Differential Analyzer (GEDA). This general purpose analogue computer is normally used for solving linear differential equations with constant coefficients. The heart of the GEDA is a group of 20 direct-coupled amplifiers which have a gain of 70,000 and a maximum output signal level of ±100 volts. The input grid current is less than 5×10^{-11} ampere, and the drift is less than 200 microvolts per hour equivalent input signal.

Special purpose devices used in the system include transducer units, which convert pulse-time data to d-c form, and servomultipliers for obtaining solutions to the nonlinear equations to be solved. The accuracy of the conversion from pulse-time to direct current is on the order of 0.05 per cent, as is the accuracy of the products obtained by the multipliers. The output data are recorded on plotting boards, producing both time and trajectory position plots, and on potentiometer recorders for co-ordinate velocities.

In flight test programs the system is particularly useful in the study of various types of pilotless aircraft where instantaneous knowledge of position and velocity is extremely important to the ground observer.

Speaking of Electric Distribution System Expansion; *H. C. Swannell* (*J. E. Sirrine Company, Greenville, S. C.*) *and J. P. Reece* (*R. J. Reynolds Tobacco Company, Winston-Salem, N. C.*).

In 1948, the R. J. Reynolds Tobacco Company of Winston-Salem, N. C., placed in operation their Bailey Power Plant 2 containing a single 12,500-kw turbine-driven generator to operate in conjunction with an existing 10,000-kw 2,400-volt plant adjacent to it. Looking forward to a future installation of a second unit in their Plant 2 of at least equal capacity and of becoming the central source of all electric power and steam requirements, the new unit was made to operate at 13,800 volts. The two plants are interconnected with bus-tie transformers, one section of the distribution changed to 13.8-kv distribution,

another section changed from 2,400 volts to 4,160 volts, and 2,400 volts were retained for certain other services. Both the 13.8-kv and 4,160-volt systems have grounded neutrals through grounding transformers.

Various Cathodic Protection Applications Using Graphite Anodes; *J. P. Oliver* (*Union Carbide and Carbon Corporation, Cleveland, Ohio*).

Corrosion is an electrochemical phenomenon that can be controlled by making the corroding metal a cathode in an electrolytic cell. This method of control is known as cathodic protection. In this manner, corrosion is completely arrested or greatly reduced on pipe lines, tank farms, chemical equipment, ship hulls, lead-covered cables, water mains, water tanks, and marine structures. Graphite anodes, because of their high electrochemical equivalent, find application in cathodic protection, for they give long life as well as being economically attractive because of their low cost and ease of installation.

Selection of the Electric Motors for Oil Well Beam Pumping; *J. N. Poore* (*General Electric Company, Dallas, Tex.*).

The beam or "sucker rod" method of pumping is used on approximately 90 per cent of all pumping oil wells. The beam-pumping unit is, in many cases, powered with a squirrel-cage a-c high-starting-torque electric motor.

The normal slip a-c motor having approximately 250 per cent starting torque is the most commonly used motor for beam-pumping service. The medium- and high-slip a-c motors, with even higher starting torque, are advantageous where it is necessary to minimize motor current peaks when power is supplied from a relatively small generating plant or where the well operates at a high number of strokes per minute.

Motors that are reconnectable for three different horsepower ratings, commonly called triple-rated motors, are used in some instances where it is likely that the pumping load will increase over a period of time because water encroaches into the oil producing reservoir.

Although totally enclosed fan-cooled motors are normally recommended for outdoor service, most beam-pumping units use splash-proof or dripproof motors outdoors with no apparent detrimental effect. Exceptions to this procedure are taken in the Gulf Coast areas and in areas where heavy snows are prevalent.

A formula for calculating the approximate motor horsepower rating required for pumping a particular well is available. It takes into account both the hydraulic horsepower required to pump the well and the friction horsepower required to operate the pumping unit. In addition, it recognizes the heating effect on the motor of the peculiar cyclic variation in motor current due to the up and down strokes of the rods on the beam-pumping unit.

Some fairly comprehensive tests have been made on motors used for oil well beam pumping. The purpose of the tests was to determine the effect of motor slip on beam-pumping applications as well as to better evaluate the loading conditions on such motors. The results of these tests were possibly indicative but not conclusive because of the relatively few wells tested. Many more tests of a similar nature are required before definite conclusions can be made.

Transient Analysis of Servomechanisms; *Andrew Vazsonyi* (*Naval Ordnance Test Station, Pasadena, Calif.*).

The conventional transient analysis of a servomechanism begins with setting up the system of differential equations governing the servomechanism and then determining the associated characteristic equation. The characteristic equation then is solved for a set of numerical parameters, and the investigator selects the parameters yielding optimum performance. If the characteristic equation is of high order, a considerable amount of work results.

The method of this paper aims to determine directly the optimum performance. Suppose, for instance, that the characteristic equation is of the fourth order. By using dimensionless variables, the system performance depends on three dimensionless coefficients. Assume now that one of the parameters (say a spring constant) can be easily varied, that only one of the dimensionless coefficients is a function of this variable, and that one is interested in the performance of the system only when the optimum value of this parameter is selected. Then the system depends only on two independent variables and a chart can be devised depicting the performance of the system for any value of these two parameters.

Certain special mathematical relationships in connection with the third and fourth order equations have been developed, and the analysis of the following specific applications is possible: (1) steam turbine governor; (2) angular positioning mechanism; (3) variable voltage angular positioning mechanism; and (4) electric turret traversing mechanism

Sagging Conductors in a Series of Inclined Spans; *H. H. Rodee* (*Aluminum Company of America, Pittsburgh, Pa.*).

To obtain the correct sags in a series of spans, the horizontal components of tension must be equal in all spans between dead ends. On a steep incline this cannot be accomplished while the conductors are hanging in the stringing blocks, which are free to turn, because the blocks will deflect in the uphill direction and there will be a horizontal component in the stringing block itself.

The Nantahala Power and Light Company solved this problem, on a line built in North Carolina in 1941, by installing the suspension clamps at locations found by applying measured off-sets at the points of support.

The conductors were pulled uphill through stringing blocks suspended from the crossarms, and dead ends were permanently installed at the first tower at the foot of the incline. Slack then was pulled uphill until the correct sag was obtained in the first span from the dead end. While in this position the tensions increased progressively from one span to the next by an amount equal to the horizontal component in the stringing block at each tower. Sags were therefore too small and lengths of conductor too short in all spans except the first from the dead end.

Off-sets were measured and marked on the conductors at each tower to provide the additional length required in each span. Dead ends then were installed at the last tower in the series at the top of the incline, and the installation was completed by installing the suspension clamps at the marked locations at the intermediate towers. After this work was done the insulators swung to a vertical position and the sags checked closely with the calculated sags.

Design and Operation of Generating Station Auxiliaries for Power System Reliability; *W. R. Brownlee, J. A. Elzi* (*Commonwealth Services, Inc., Jackson, Mich.*).

Within optimum economic limits, full output should be maintained at steam electric generating stations during sustained low-frequency and low-voltage conditions which result from infrequent major system disturbances. The design and operation of electrically driven auxiliaries can provide for such emergencies.

During recent years some 16 system disturbances which occurred in a large interconnected area were of sufficient importance to warrant special consideration and analysis. The connected generation of the affected area ranged from 16,000 megawatts to 1,600 megawatts and the generation drop varied from 100 to 400 megawatts.

From a study of system and plant performance during these disturbances, from test data obtained on intentional reduced voltage operation of a large modern steam electric unit, and from theoretical considerations, some conclusions regarding this problem have been drawn.

1. The reliability of electric drives properly designed has been demonstrated.
2. Appropriate margins in auxiliary drives must be provided.
3. Margins designed into auxiliary drives for other contingencies may also provide a substantial portion of the margin required during sustained system disturbances.
4. Observation of some major system disturbances shows frequency reductions from 0.2 per cent to 5.0 per cent.
5. An analytical approach weighted by tests and operating data indicates that station auxiliary systems should be designed to provide for maximum generation with
   a. System frequency five per cent below normal.
   b. Simultaneous voltage 80 per cent of normal (equivalent to an additional 1-per cent low frequency at normal voltage).

Large Motors for Power House Auxiliaries; *Quentin Graham* (*Elliott Company, Inc., Ridgway, Pa.*).

Five years ago, the AIEE held a symposium on central station auxiliaries, including a thorough discussion of motor drives. Today, most of the ideas and opinions expressed in the 1945 meeting would be unchanged. The matter of reliability under conditions of dirt, moisture, and continuous usage was then, and is still, uppermost in the minds of operating engineers.

Progress in powerhouse auxiliary motors over the past five years has been largely along two paths: (1) Development of motors for outdoor service; and (2) Development of totally enclosed fan-cooled motors in the larger sizes.

With the greatly increased use of outdoor power stations, it became evident that ordi-

nary splashproof motors were not protected sufficiently for this service, particularly in regions where wind and rain achieved hurricane proportions. To meet these conditions, various protective devices were added to the inlet and outlet openings, but while these enclosures had some degree of success they were at best makeshifts. Finally, an integrated design was attempted, with the result that a satisfactory weatherproof motor was developed. Tests on these new motors under fine water spray, direct fire hose, and other storm-simulated conditions, have shown that water is excluded completely from the windings.

In the larger size totally enclosed fan-cooled motors, because of the inherent lower ratio of surface to volume, it becomes necessary to use a more elaborate means of cooling than is required for smaller motors. A number of solutions are available, and the choice between them becomes a matter of reliability and ease of maintenance.

The motor described was developed for station auxiliaries for either indoor or outdoor installations. It has a separate air-to-air cooler which is readily removable for inspection, cleaning, or replacement, or may be easily cleaned in position.

Normally the coolers are placed at the top of the motor, thereby minimizing the floor space which is required. Other cooler locations are possible, although economy of floor space is generally of more importance than head room.

For outdoor stations, the outdoor splashproof motor is the least expensive type that meets the minimum requirements for the service desired. Still better protection against dirt and moisture, but at an additional cost, is provided by totally enclosed fan-cooled motors.

The choice of type will have to be made by operating engineers, who must balance reliability and maintenance costs against added investment. The motor manufacturer stands ready to supply both types.

The Effect of Frequency Reduction on Plant Capacity and on System Operation; *H. A. Bauman, G. R. Hahn, C. N. Metcalf (Consolidated Edison Company of New York, Inc., New York, N. Y.).*

At times there may be a deficiency of generation which makes it impossible to meet current needs. It is well known that reduction of voltage will reduce the load, and this has been applied in many instances as a load relief procedure. It has been proposed and some systems have utilized a reduction in frequency as a means of reducing load.

Tests were made in order to determine the effect of reduced frequency on plant capacity with special regard to cases where, by reason of some emergency, there is a deficiency of generation and the system frequency decreases.

The major effects of a 10-per cent reduction in frequency on steam generating station capacity and on interconnected systems are:

1. The reduced speed of motor-driven generating station auxiliaries, such as fans, pumps, and mills, will bring about a reduction of plant output by as much as 30 per cent, whenever these auxiliaries are operating at maximum capacity.

2. Turbine capability is reduced approximately one per cent, which may prove to be a serious limitation in an emergency. Due to the limited range of turbine governor speed changers, difficulty in synchronizing additional generators to the bus will generally occur when frequency is two to five per cent below normal.

3. Generator efficiency is very slightly affected; however, reduced speed of the generator cooling fans will reduce the capacity of the cooling system, which may affect the thermal limits of the machine.

4. Reduced frequency at any point of a system pulls down the speed of the entire interconnection. This is in marked contrast to the effective use of voltage reduction wherein it is possible to localize the voltage reduction to the area requiring load relief.

5. The characteristic of connected load will affect the results obtained by frequency reduction. Tests made on the Consolidated Edison System show that a frequency reduction of three per cent, with bus voltage kept constant, produced no measurable load change.

6. Since frequency reduction results in no-load rejection on the system but introduces the liability of reduced plant output, Consolidated Edison Company uses voltage reduction as the initial means of obtaining load relief, and if this proves to be insufficient, then blocks of customer load are dropped.

Problem Preparation for a Digital Computer; *D. H. Gridley, B. L. Sarahan, J. S. Seward (Naval Research Laboratory, Washington, D. C.).*

The Naval Research Laboratory Electronic Digital Computer (the NAREC) is a high-speed parallel-type digital computer. This complex combination of electronic circuits is an efficient and useful device for computation only if the machine is provided with the proper instructions necessary for the desired numerical solution. An instruction to the machine specifies the operation to be performed as well as the location of the number involved in the operation. Such instructions provide for the arithmetic operations, the insertion and extraction of information, and the transfer of numbers between circuits of the NAREC. Normally, the control section of the computer executes these instructions in a sequential manner but orders are provided to alter this sequence if desired.

The numerical solution of the simple differential equation

$$L\frac{di}{dt}+Ri=E$$

which describes the condition of dynamic equilibrium for a series-connected resistance-inductance circuit, serves as an example of the combined use of these instructions. A hundred values of i can be computed on a machine with the planned capabilities of the NAREC in less than 0.25 second. The complete computation requires about 5,400 operations (but only 147 instructions, since most instructions are used several times). Additional processing of the input and output data increases the total computation time to five seconds.

A considerable amount of labor is involved in formulating and coding a problem for solution on a high-speed computer. The point at which this effort becomes justified depends on the complexity of the problem, the type of machine available, and the skill of the programmer in placing the problem in a form suitable for a given machine. The accuracy of the results obtainable on a machine of this type are limited only by the accuracy of the input information and the mathematics of the problem.

Selection of A-C Motors for Driving Oil Well Pumping Units; *M. H. Halderson (Phillips Petroleum Company, Bartlesville, Okla.).*

Many types of a-c motors are used to drive oil well pumping units. The diversity of choice of motors suggests that the various types are equally desirable, but this is not the case. Experience and a more fundamental approach to the evaluation of motors for oil well pumping substantiate the conclusion that five- to eight-per cent slip motors in a dripproof or protected frame should be purchased for installations where 3-phase power is available. Two-value capacitor-type motors in a dripproof or protected frame are preferred for the small per cent of installations where single-phase power must be used.

Motors with five- to eight-per cent slip are preferred for driving pumping units because they have the best starting characteristics and because, compared to normal slip motors, they will carry 35 per cent more load per name plate rating, will operate with 20 points higher power factor, and will operate with 25 per cent less peak power input. Dripproof or protected frame motors are preferred because motors built in these frames have the greatest thermal capacity per dollar invested and because experience has shown that these frames provide ample protection for outdoor operation.

Because of high power peaks and the wide load variation, motors installed on pumping units cannot average an output equal to name plate rating without being thermally overloaded. Based on 17 tests in the field, the recommended procedure for sizing the two types of motors most frequently used for oil well pumping is to assume that five- to eight-per cent slip motors can average an output equal to 76 per cent of name plate rating and that normal slip motors can average an output equal to 56 per cent of name plate rating.

Field Vibration of a Large Frequency Changer

W. M. H. BALLANTYNE
MEMBER AIEE

J. E. ALLEN
FELLOW AIEE

R. A. BAUDRY

A LARGE FREQUENCY CHANGER was installed in 1934 at the Safe Harbor Power Station to supply 25-cycle power to the Pennsylvania Railroad. It consists of a 24-pole 3-phase 60-cycle synchronous motor rated at 29,000 kva at 90 per cent power factor solidly coupled to a 10-pole single-phase 25-cycle generator rated 31,250 kva at 80 per cent power factor.

When placed in service the machine performed satisfactorily. There was only a small amount of 50-cycle vibration caused by the single-phase torque.

In 1937, it was thought advisable to retighten the split of the core. The machine continued to operate satisfactorily until 1939 when the effect of vibrations became noticeable on the windings and end bells. After a further increase of the amplitude of vibration a thorough investigation was made which showed that:

1. The fundamental frequency of the vibration was 50 cycles per second, the same as the frequency of the magnetic forces produced by the armature flux.
2. The vibration existed only when the field was on and was nearly proportional to the field current.
3. The amplitude of vibration did not change when the load was increased from 0 to 15,000 kw. This indicated that although the vibrations were of magnetic origin they were not caused by the leakage flux of the end windings.
4. The vibration of the end bell was proportional to the stator vibration and reached a large value at the normal speed of 300 rpm, thus indicating a condition of resonance near this speed. The resonant point was found to change with field current and armature temperature.

It was concluded that the end bell vibrations were caused by the stator vibration resulting from the large magnetic forces acting on the split. The resonance condition is changed by the pressure in the split, resulting from the split bolt tightness, core temperature, and field strength. This explained the original freedom from vibration and the change in resonant condition caused by the retightening of the split bolts and the reducing of the water flow in the coolers which resulted in higher core temperature.

Further analysis of the problem showed that the easiest way to eliminate vibration was to move the natural period of vibration of the stator away from the operating speed. This was done by putting a heavy steel support under the stator. The stator vibration was reduced at normal speed from 0.0085 to 0.001 inch, and the end bell vibration near the shaft reduced to 0.006 inch.

A similar investigation made on the stator of the 60-cycle motor showed that it was entirely free from vibration. Building up of appreciable vibrations is prevented because the smaller core size results in much smaller magnetic forces and the stator frame is supported on a cradle securely bolted to the foundation.

Indications of rotor vibrations were first noticed during the early stator vibration investigations when fatigue cracks were found on field leads and pole punchings. The presence of red iron-oxide dust indicated that the poles were vibrating relative to the spider.

DeForest scratch gauges were installed on the poles and spider. Some of the scratch gauges were provided with a triggering device which permitted taking readings under any desired operating condition.

These tests showed that the pole moved away from the spider at normal speed; in addition, there was vibratory motion of the pole relative to the spider consisting of a 5-cycle motion caused by gravity superimposed on a 50-cycle motion caused by the single-phase torque.

An analysis made following the scratch gauge tests showed that to eliminate pole vibration it was necessary that the base of the pole would seat tightly against the spider at normal speed by preloading the dovetail equal to or greater than the centrifugal force of the pole and coil at normal speed. It was also shown that for such a long pole the axially driven dovetail wedges did not have sufficient cross section to overcome the friction forces which would occur while producing the required preloading of the dovetail.

Use of a novel type of self-tightening tangential wedges placed between the pole and the spider made it possible to obtain the necessary preloading of the dovetail.

These wedges were tightened by running the machine 15 per cent overspeed, thus raising the pole away from the spider, and allowing the new wedges to be driven tangentially by springs. When the speed was reduced to normal, the pole became firmly seated on the tangential wedges.

Measurements by means of scratch gauges made following the installation of the tangential wedges and after several years of operation showed that the pole rocking and resulting trouble had been eliminated. The tangential wedges can be retightened very easily by running the machine at 15 per cent overspeed.

On the 60-cycle 3-phase motor the gravity forces and the pulsating torque are much smaller than on the 25-cycle single-phase generator. Scratch gauge measurements made on the poles of this 60-cycle machine showed that the pole rocking which could be detected at maximum load was practically negligible.

As large slow-speed machines cannot be assembled in the plant, minor adjustments must be made in the field.

Digest of paper 50-199, "Investigation and Elimination of Unusual Vibration in the Field on a Large Single-Phase Frequency Changer," recommended by the AIEE Committee on Rotating Machinery and approved by the AIEE Technical Program Committee for presentation at the AIEE Middle Eastern District Meeting, Baltimore, Md., October 3–5, 1950. Scheduled for publication in AIEE *Transactions*, volume 69, 1950.

W. M. H. Ballantyne (deceased) was with the Safe Harbor Water Power Corporation, Baltimore, Md.; J. E. Allen (deceased) was with the Safe Harbor Water Power Corporation, Lancaster, Pa.; and R. A. Baudry is with the Westinghouse Electric Corporation, East Pittsburgh, Pa.

INSTITUTE ACTIVITIES

Sixty Technical Sessions Scheduled for Winter General Meeting

Plans for the 1951 Winter General Meeting to be held during the week of January 22–26, 1951, are rapidly taking shape. The meeting headquarters are at the Hotel Statler, Seventh Avenue and 33rd Street, New York 1, N. Y.

The technical program will consist of approximately 60 sessions. Among these is one sponsored by the Committee on Telegraph Systems in which papers will be presented on An Electronic Time Division Multiplex Telegraph Set, A Teleprinter Signal Bias Meter, and a Nationwide Telegraph System Using Frequency-Modulated Carrier Equipment. An additional session is being sponsored by the subcommittee on Electrostatic Processes in which it is expected that papers on particle charging in electrostatic precipitation will be given. The theoretical aspects of the particle charging both by electrical impact and by diffusion of ions will be covered, plus a review of laboratory and field experimental results. A paper in this same session is entitled Distribution of Charge in Electrostatic Separation in which the measurement of the charge, the graphical relationship in the deflection data, the charge versus deflection distance, and the deflection data and the normal law data are compared. An additional paper is expected on the Electrostatic Sources of High-Energy Ionizing Power.

The Committee on Substations has two papers promised which will discuss the Considerations That Led to Radial Distribution with Bus Regulation in Preference to Primary or Secondary Networks in the City of Los Angeles, and the Isolation of Faults on Electric Transit Distribution Systems. Two additional papers will be presented on the subjects of The Trend Toward Bus Regulation on the System of the Detroit Edison Company and Direct Current Power Supplies.

A symposium on magnetic materials at high frequencies is scheduled in which four papers on the properties, production, and measurement of these materials will be discussed by prominent authorities in this field. Four outstanding scientists will also take part in a session on radiation detection devices including a discussion of the tubes as well as the apparatus itself.

TENTATIVE SCHEDULE

Monday, January 22

Relays and Instrument Transformers	Safety
Instruments and Measurements	Basic Sciences
Electronic Power Converters	Carbon Brushes

Tuesday, January 23

Relays and Industrial Power Systems	Management
Electrical Properties of Gases	Therapeutics
Instruments and Measurements	Rotating Machinery
Magnetic Materials	Electronic Education
Chemical Industry	Protective Devices
Industrial Control	Cathodic Protection

Wednesday, January 24

Transformers	Communications
Rotating Machinery	Electric Welding
Electronics	Insulated Conductors
Electric Circuit Theory	Education
Instruments and Measurements	

Thursday, January 25

Transmission and Distribution	Communications
Transformers	Industrial Power
Rotating Machinery	Substations
Electronics	System Engineering
Computing Devices	Fluorescent Lamps
Space Heating and Heat Pumps	

Friday, January 26

Switchgear	Communications
Power Generation	Feedback Control
Electronics	Land Transportation
Transmission and Distribution	

THEATER TICKETS

It is expected that tickets will be available for various Broadway shows. Those members wishing seats should write AIEE Headquarters at an early date to insure best choice of seats and productions. Requests should include name of show, date, number of seats required, and check to cover cost of tickets. In the case of tickets in short supply, the right is reserved to allocate seats only to members attending from points beyond the New York metropolitan area.

Tickets for the following shows are not available:

Call Me Madam; Guys and Dolls

Some current productions and prices are:

	Evening, Orchestra	Matinee, Orchestra
Affairs of State	$4.80	$3.60
*Gentlemen Prefer Blondes	6.00	3.60
*Kiss Me Kate	6.00	3.60
The Lady's Not for Burning	4.80	3.60
Season in the Sun	4.80	3.60
The Cocktail Party	4.80	3.60
The Happy Time	4.80	3.60
The Member of the Wedding	4.80	3.60
Bell, Book and Candle	4.80	3.60

* Indicates Musical.

LADIES' ENTERTAINMENT

The Ladies' Entertainment Committee, under the chairmanship of Mrs. R. F. Brower, is planning a dinner party with entertainment the evening of Tuesday, January 23, and has arranged for a Fashion Show and Luncheon at the Plaza on Thursday, January 25. The Fashion Show will be staged by Henry Rosenfeld, Inc., New York. There will be a Tea Get-Together at Ladies Headquarters Monday, January 22.

DINNER DANCE AND SMOKER

The dinner dance, always a popular highlight of the evening entertainment program, will be held in the main ballroom of the Hotel Statler on Thursday evening, January 25, at 7 p.m. Formal dress is requested. More than 350 people attended last year's dinner dance and enjoyed an evening of good food, pleasant conversation, and general sociability. Dinner tables again will be kept clear of the dance floor, allowing groups to remain at the same table for the entire evening and avoiding the confusion of having to move furniture before the dancing.

Consolidated Edison Company of New York, Inc., photo

The Times Square area of New York City at night looking north from 34th Street at the junction of Broadway and the Avenue of the Americas. The haze of light in the upper right-hand corner is caused by the many signs and marquees of Broadway

Reservations may be made with the Dinner Dance Committee, AIEE Headquarters, 33 West 39th Street, New York 18, N. Y. Each table will seat 10 persons. It is expected that tickets will cost $11.00.

The Smoker Committee, under the chairmanship of D. M. Quick, announces that the Smoker will be held on Tuesday evening, January 23, at the Commodore. It is urged that members send their reservations to the Smoker Committee, AIEE Headquarters, at an early date. Indications are that the price will be $8.00 per ticket.

INSPECTION TRIPS

The Inspection Trips Committee, under the chairmanship of F. P. Josslon, is making every effort to make interesting inspection trips available, but, because of the security regulations currently in effect at various plants, definite commitments and an announcement of the trips to be offered cannot be made at this time.

HOTEL ACCOMMODATIONS

Blocks of rooms have been set aside at the Hotel Statler (meeting headquarters) and near-by hotels for members attending. To assure accommodations, reservations must be received by the hotel of choice before January 12. Requests for reservations should be sent early directly to the desired hotel, and to only one hotel. A copy of the request should be sent to Mr. C. N. Metcalf, Chairman, Hotel Accommodations Committee, in care of Consolidated Edison Company of New York, Inc., Room 1250-S, 4 Irving Place, New York 3, N. Y. A second and third choice should be indicated on this copy. If requested accommodations are not available, the Hotel Accommodations Committee will arrange for transfer to one of the other hotels desired.

Hotel rooms have been reserved at:

Hotel Statler (meeting headquarters) 7th Avenue, 32d to 33d Streets

Single room with bath	$ 5.00 to $ 8.50
Double room, double bed	7.50 to 10.50
Double room, twin beds	9.00 to 14.00
Parlor suites	19.00 to 33.00

Hotel McAlpin, Broadway and 34th Street

Single room and bath	4.50 to 8.50
Double room, double bed	7.00 to 10.50
Double room, twin beds	8.50 to 11.00
Suites	14.00 to 15.00

Hotel Governor Clinton, 7th Avenue at 31st Street

Single room with bath	4.50 to 7.00
Double room, double bed	7.00 to 10.00
Double room, twin beds	8.50 to 10.00

Hotel New Yorker, 34th Street at 8th Avenue

Note: Reservations for arrival January 20th or 21st ONLY. Write to D. W. Carlton, Director of Sales.

Single room, tub and shower	$4.50 to $8.00
Double room, double bed	7.50 to 12.50
Double room, twin beds	8.50 to 12.50
Suite accommodations	14.00 to 25.00

Hotel Martinique, Broadway and 32d Street

Single room with bath	3.50 to 6.00
Double room, double bed	6.00 to 10.00
Double room, twin beds	6.50 to 10.00
Two-room suites	10.00 to 18.00

(Rate for single room with bath was listed incorrectly in the November issue.)

Hotel Commodore, 42d Street at Lexington Avenue

Single room with bath	6.00 to 9.00
Double room, twin beds, bath	10.50 to 12.50

WINTER GENERAL MEETING COMMITTEE

The members of the 1951 Winter General Meeting Committee are G. J. Lowell, *Chairman;* C. T. Hatcher, *Vice-Chairman;* J. J. Anderson, *Secretary;* W. J. Barrett, *Budget Co-ordinator;* C. S. Purnell, *Vice-President, District 3, AIEE;* C. H. Willis, *Technical Program;* J. D. Tebo, D. W. Taylor, D. T. Braymer, *General Session;* N. S. Hibshman, *Medals;* G. T. Minasian, J. B. Harris, Jr., *Publicity;* C. N. Metcalf, *Hotel Accommodations;* E. R. Thomas, *Registration;* D. M. Quick, *Smoker;* Mrs. R. F. Brower, *Ladies' Entertainment;* E. S. Banghart, *Dinner-Dance;* F. P. Josslon, *Inspection Trips;* J. B. Paszkowski, *Theater-Radio.*

Program

AIEE—IRE Conference on Electron Tubes for Computers

(In Collaboration with the Panel on Electron Tubes of the Research and Development Board)

Atlantic City, N. J., December 11–12, 1950

Monday, December 11

9:30 a.m. Computer Experience with Electron Tubes

Chairman: Mina Rees, Office of Naval Research

Review of AIEE Conference on Electron Tubes for Instrumentation and Industrial Use. *W. R. Clark,* Leeds and Northrup Company

Experience with Receiving-Type Vacuum Tubes on the Whirlwind Computer Project. *E. S. Rich,* Massachusetts Institute of Technology

Electron Tube Experience in IBM. *J. A. Costz, E. W. Brooks,* International Business Machines Corporation

Performance of Electron Tubes in the ENIAC. *Wright E. Ervin, Homer W. Spence,* Aberdeen Proving Ground

1:30 p.m. Electron Tube Problems

Chairman: S. N. Alexander, National Bureau of Standards

Design and Operation of Tubes for Long Life. *J. O. McNally,* Bell Telephone Laboratories

The JETEC Approach to the Tube Reliability Problem. *J. R. Shea,* Sylvania Electric Products, Inc.

Cathode Inter-Face Impedance and Its Effects in Aged Vacuum Tubes. *H. B. Frost,* Massachusetts Institute of Technology

Cathode Impedance and Tube Failure. *L. S. Norgaard,* Radio Corporation of America Laboratories

6SN7WGT and 6AN5; Mutual Conductance Dispersion and the Effect of Low Duty Cycle Operation on Long Life Performance. *I. Levy,* Raytheon Manufacturing Company

Improved Electron Tubes for Computers. Open Discussion

8:00 p.m. Special Purpose Computer Tubes

Chairman: A. L. Samuel, International Business Machines Corporation

A Stable Binary Electrostatic Storage System. *A. M. Clogston,* Bell Telephone Laboratories

Recent Experiences with the Selective Electrostatic Memory Tube. *J. Rajchman,* Radio Corporation of America Laboratories

The MIT Storage Tube. *P. Youtz,* Massachusetts Institute of Technology

The Development of the Rogers Additron. *T. Van Dyk,* Rogers Majestic, Ltd.

A Proposal for a Binary Adder Tube Utilizing Beam Deflection Principles. *D. H. Gridley,* Naval Research Laboratory

Special Cold Cathode Discharge Tube for Counting and Switching Applications. *M. W. Wallace, J. Hoag,* Federal Telecommunication Laboratories

A Decimal Counting Tube. *T. R. Kohler,* Philips Laboratories

New Improvements and Applications in Remtron Counter Tubes. *Frank J. Costz,* Remington Rand Corporation

Tuesday, December 12

9:00 a.m. Tube Manufacture and Crystal Diode Experience

Chairman: J. G. Brainerd, University of Pennsylvania

Design and Manufacture of Electron Tubes for Electronic Computer Service. *R. E. Higgs, H. E. Simms,* Radio Corporation of America

Problems in the Manufacture of Special Tubes for Computer Usage. *R. L. McCormack,* Raytheon Manufacturing Company

Development of the 7AK7. *R. W. Slaikman,* Sylvania Electric Products, Inc.

Application of Germanium Diodes in Computers. *N. DeWolf,* General Electric Company

SEAC Experience with Germanium Diodes. *J. H. Wright, R. J. Slutz,* National Bureau of Standards

Crystal Diode Life Experience in the Whirlwind Computer Circuits. *H. B. Frost,* Massachusetts Institute of Technology

1:00 p.m. Williams Type Storage

Chairman: J. H. Bigelow, Institute for Advanced Study

Tube Experience in the SWAC. *H. D. Huskey,* National Bureau of Standards

SEAC Storage Tube Memory System. *William Davis,* National Bureau of Standards

The Selection of Cathode Ray Tubes for Williams Storage. *J. H. Pomerene,* Institute for Advanced Study

Apparatus for Selection of CRT's for a Williams Storage. *David Friedman,* National Bureau of Standards

Theory of Storage in CRT's. *J. Kates,* University of Toronto

Comments on Electronic Mechanism in Williams Storage Technique. *A. Holt,* National Bureau of Standards

Broad Program Presented at Fall General Meeting in Oklahoma City

The Oklahoma City Section was host to a well-arranged Fall General Meeting which was held with headquarters in the Skirvin Hotel, October 23–27, 1950. In 25 sessions 122 technical and conference papers were presented in four broad divisions of technical activities: communication, industry, power, and basic sciences and electronics. Some of the sessions were particularly appropriate to the region in which they were held, such as the two on oil and oil well pumping, the mining and metal industries session, large-scale computing devices and their application to the chemical and petroleum industry, the industrial power systems session, and the conference on cathodic protection. On the business side, an all-day meeting of the Board of Directors was held, as well as the first Forum of Technical Committee Chairmen since the expansion of the Technical Committee structure (see page 1126), and 15 other committee meetings. Other meeting features included a General Session, Joint Luncheon with the Oklahoma City Chamber of Commerce, dinner-dance, stag smoker, a special program for the ladies, and inspection trips to nearby industries. A total of 1,144 members, guests, and students attended the meeting.

GENERAL SESSION

The General Session held on Tuesday morning was comprised of three addresses: "Welcome to Oklahoma" by H. R. Fritz, Vice-President of District 7; "The Obligations of International Leadership" by Dr. H. G. Bennett, President, Oklahoma Agricultural and Mechanical College; and "Are You an Engineer?" by President T. G. LeClair. The presiding officer was W. B. Stephenson, General Chairman of the Fall General Meeting Committee.

Welcome to Oklahoma. A cordial welcome to the South West District and in particular to Oklahoma and Oklahoma City was extended by H. R. Fritz. He explained that Oklahoma is a young state and that Oklahoma City had its first house some 61 years ago whereas there were now over 300,000 homes. Early in the '20's, there were only two sections, St. Louis and Kansas City, in the South West District which comprises a very large territory; today, there are some 13 sections and 5 subsections in the district. He complimented the Oklahoma City Section on the arrangements of the meeting, and expressed gratefulness for their efforts.

The Obligations of International Leadership. Dr. H. G. Bennett reviewed some of the social changes which have taken place and the collapse of empires during the Twentieth Century. He referred to mass production, mass education, social integration, and international defense as four important factors which are effectuating great social change. To meet these changing conditions and avoid violent social revolution, Dr. Bennett stated that this century must see a successful transition from the era of international anarchy, which preceded the first World War, to an era of international law, order, and co-operation, and that this will require a moral leadership of the highest order.

In discussing the obligations of international leadership, Dr. Bennett pointed out that we cannot dictate; we must lead through the power of prestige, might, economic strength, and intellectual as well as moral leadership. He took stock of the tools we have available to produce that kind of leadership. With regard to military preparedness, he made these points: the need for universal military training and the necessity for going far beyond mere mobilization and training of all American youth; protective public health measures; provisions for adequate specialized training of thousands of young people in scientific, technical, and commercial fields. With reference to economic mobilization, we are in somewhat better shape and factory conversion can be effected more rapidly than was possible in 1940. In regard to international economic strength, he cited that much has been accomplished in the stabilization of world economy through the establishment of the import-export banks and full participation in the Bretton Woods covenant. However, there is need to do more and the limited objectives of the old dollar diplomacy must be abandoned completely. In regard to intellectual leadership, he explained that the American policy of universal public education of all children has been thoroughly vindicated by the necessity for literacy in a scientific age. A warning was sounded, however, in regard to government and

Electrical World Photo

Three of the speakers at the General Session with Professor F. G. Tappan, University of Oklahoma, and W. G. Barrett, Chairman of the Finance Committee. From left to right: Dr. H. G. Bennett, President of Oklahoma Agricultural and Mechanical College; Professor Tappan; President LeClair; W. G. Barrett; and Vice-President H. R. Frits

Future AIEE Meetings

AIEE/IRE Conference on Electron Tubes for Computers (page 1122)
Chalfonte-Haddon Hall Hotel, Atlantic City, N. J.
December 11–12, 1950

AIEE/IRE/NBS Conference on High-Frequency Measurements (page 1129)
Hotel Statler, Washington, D. C.
January 10–12, 1951

Winter General Meeting (page 1121)
Hotel Statler, New York, N. Y.
January 22–26, 1951
(Final date for submitting papers—closed)

Southern District Meeting
Miami, Fla.
April 11–13, 1951
(Final date for submitting papers—January 11)

North Eastern District Meeting
Syracuse, N. Y.
May 2–4, 1951
(Final date for submitting papers—February 1)

Great Lakes District Meeting
Madison, Wis.
May 17–19, 1951
(Final date for submitting papers—February 16)

Summer General Meeting
Royal York Hotel, Toronto, Ontario, Canada
June 25–29, 1951
(Final date for submitting papers—March 27)

Pacific General Meeting
Portland, Oreg.
August 20–23, 1951
(Final date for submitting papers—May 21)

Fall General Meeting
Hotel Cleveland, Cleveland, Ohio
October 22–26, 1951
(Final date for submitting papers—June 22)

Electrical World Photo

Attending the Fall General Meeting in Oklahoma City, left to right: Director N. B. Hinson, Junior Past-President J. F. Fairman, Vice-Presidents R. A. Hopkins and C. G. Veinott

Electrical World Photo

Group of authors at Conductor Vibration Session. Left to right: P. G. Wallace, Texas Power and Light; M. B. Elton, Bonneville; A. A. Osipovich, Bonneville; J. Lummis, Southern California Edison

industries seriously outbidding the colleges for young men and women of exceptional talent who should be attracted to college teaching. Dr. Bennett gave the highest priority of all to moral leadership, pointing out that there can be no morals without religion and citing the collapse of Germany as an example. Democracy has not outlived its usefulness, for no other ideology conceived or existing meets the requirements of changing orders. Democracy alone can adjust and readjust and modify its forms and processes to the end that all men shall be free, shall be secure, and shall have the right to hope.

Dr. Bennett concluded: "We must be strong: in might to make the right prevail; in economic foresight, leadership, and production, to sustain a starving, ravaged world; in intellectual thought and talent, to solve the problems of intricate complexity which dog a world that is filling up with people; in religious and moral conviction, to insure that our leadership shall not be repudiated. America must not merely survive—she must lead the way to a better world."

Are You an Engineer? In an address presented before the General Session, President LeClair explained that the necessity for a definition of an engineer has been brought about by the larger amount of complex machinery and the rising standard of competence required for an ever-increasing number of engineers. In the long run, the profession would benefit by having a standard of competence which would prevent the work of unqualified persons from reflecting on the name of the profession. The origin of engineering was traced historically from the time of Archimedes on through today's diversified specialties and organizations.

President LeClair feels that the profession should have a spokesman on questions of state-wide or national importance. The Institute has taken a leading part toward unification among engineers and was active in the formation of the Exploratoy Group on Unity in the Engineering Joint Council. It was announced that Past-President J. F. Fairman is now the Institute representative on the Exploratory Group and on the Planning Committee which is doing most of the spade work for the larger group. Substantial progress has been made, but on such a broad subject considerable time will be required before a true standard of unity can be reached.

There has been a steady growth over the past 50 years in the number of organizations which call themselves engineering societies. President LeClair pointed out that because almost all of them have different standards of qualifications for membership and cover widely different fields it is time to determine where the fringe between engineering and some other perhaps equally good endeavor is. He spoke of the need to find some common core which goes through all of these different specialties which can be recognized as the necessary foundation for the profession. He analyzed and discussed the problem from the points of view of fields of endeavor and levels of qualifications, considering the different degrees in the colleges and the different requirements for professional registration in the several states. He referred to the standards for qualification in the legal and medical professions which are more uniform, and to the progress the Engineers Council for Professional Development has made on the problem of adopting a uniform standard of qualification for membership in the engineering societies, and he expressed hope that this problem might be solved in a very few years.

In conclusion, President LeClair considered the human side of the problem and discussed what constitutes being a good engineer. To him, the only true engineer is one who wishes to give service to mankind far above and beyond the minimum need of his job. He also referred to the teaching profession as serving just as important a role by the inspiration which a teacher of engineering imparts to each student to advance the art and science of the profession.

TECHNICAL SESSIONS

Technical sessions were held in four broad fields of endeavor: communication, industry, power, and basic science and electronics. The papers in the session on moderate haul telephone and television systems as well as those in the session on communication switching systems were particularly appropriate in the region of the meeting. Among the several sessions in the power field considerable interest was evidenced in the conductor vibration session held on the first day of the meeting.

Conductor Vibration. Ten papers were presented which gave information on the latest experiences and corrective measures to reduce conductor vibration and minimize failures attributable to this phenomenon. The papers represented a wide geographic distribution of operating experience extending in an arc from Bonneville in the Pacific Northwest down through Southern California, Colorado, Oklahoma, and Texas on up to Ontario, Canada. The investigations and laboratory techniques of wire manufactures also were reported. One possible outcome of the session might be the lowering of the sag and tension in overhead steel ground wires. However, conductor vibration was considered to be still an unsolved problem and belief was expressed that much work remains to be done. Any solution to date is still not a fundamental one and the interest evidenced at the meeting should be sustained throughout the industry. The session was presided over by A. E. Davison of the Hydro-Electric Power Commission of Ontario.

Symposium on Supervisory Instruments. Five papers were presented in the symposium, with J. A. Brooks presiding, which treated various phases of this currently popular subject which is important in reducing the cost of electric power plant operations.

The first paper, "The Supervisory Instrument—Its Contribution to Centralized Control" by T. T. Frankenberg, pointed out progress which has been made in the reduction of manpower requirements for operation of steam-electric generating stations. It showed that present-day stations generate as much as 50 megawatts per shift operator as compared with 7 megawatts per shift operator in stations designed 20 years ago. The presentation also showed how the supervisory instrument has contributed to ease in operating steam-electric power plants.

Another paper, entitled "Centralized Control Board for Steam-Electric Generating Plants" by H. L. Lowe and R. L. Hodgkins, described a particular design of central control board incorporating on one board combustion controls, steam turbine controls, a-c generator controls, excitation controls, and controls for station light and power. The board described in the paper is probably the most advanced board in existence today.

The third paper presented, "Instruments for Detection of Toxic and Explosive Gases," drew attention to the needs for gas and contaminant detectors in power plants, and the development of such instruments as well as designs now in use were described.

"Improving Surface Condenser Performance Through the Use of Supervisory Instruments," by J. G. Dobson, described a group of instruments which can be used for indicating and recording condenser performance. Such matters as condensate purity, condenser air leakage, absolute pressure on the steam side, and the differential pressure between water boxes can be indicated and recorded with alarms and shutdown mechanisms combined, if desired.

Another paper, "High Speed Supervision of Process Variables" by W. E. Belcher, Jr., described still another type of instrument which can be used for monitoring one or more operating factors such as temperature, pressure, flow, and position. These systems can have audible alarms and can be set up for continuous loggings or for intermittent loggings for particular conditions.

Power Generation. The session on Power Generation, with B. G. A. Skrotzki presiding, dealt with a variety of subjects such as induced currents in high capacity bus enclosures, a continuous scavenging system for hydrogen-cooled generators, control of gas turbines for power generation, and thrust bearing problems. In connection with the new system for hydrogen-cooled generators, most of the discussion was related to the economics; L. P. Grobel, the author who made the presentation, explained that the main asset to the user would be the realization of lower maintenance costs due to the use of less piping and equipment. C. J. Fechheimer of Milwaukee expressed the belief that some day they would have liquid cooling with attendant savings in the foundations and buildings.

"Control of Gas Turbines for Power Generation," which was read by A. G. Mellor, marked an advance in the subject, and presented problems met in putting a turbine on the line, taking it off the line, and controlling its load. The starting and stopping of the gas turbine consists of a sequence of steps which must be performed in proper time intervals. J. W. Blake reported on the operation of the gas turbine which has been in service a little over a year in the Huey station. Operation has been very satisfactory and the governing unusually good, proving earlier fears unfounded.

In connection with the presentation of the thrust bearing problems paper, a discussion by Ray Shepherd of the General Electric Company was read by C. Concordia. One of the points concerned the placing of thermocouples in the oil line to determine the bearing loading rather than in the two shoes each side of the plate. The author replied that the placing of thermocouples in the bearing which were connected to a recorder indicated a temperature rise of 200 degrees in starting which never would have been detected with the thermocouples in the oil line.

Electronic System Engineering. Five papers were presented in this session which evoked considerable interest. In introducing the subject, H. L. Flowers, who presided over the session, explained that the papers represented new ideas that have been applied to systems engineering this year and that they record the progress in the applications of those ideas. Since the first announcement by Norbert Wiener in regard to the mechanism of body control, interest has quickly spread throughout the industry particularly in the fields of airplanes, gunfire control, and other operations which depend on human reactions. Mr. Flowers presented "Some Engineering Aspects of the Mechanism of Body Control" for the author, Robert Mayne, and the response of the human operator to various kinds of inputs was illustrated with lantern slides. In conclusion, he explained that an attempt had been made to outline a mechanism of body control which of necessity was incomplete and only consisted of a status control. In discussion, Professor Travers of the Massachusetts Institute of Technology Servomechanisms Laboratory referred to a proposed approach to the problem through the medium of noise in the new laboratory. Professor A. D. Moore referred to animal dynamics and the need of biologists for assistance in this field. From a personal acquaintance with Willie Hoppe, the billiard player, he explained that in a highly trained skill the conscious control drops out.

An interesting application of information theory to the problem of aircraft traffic control over a busy airport was presented by W. G. Tuller. Such a rapid safe communication system from a ground controller to aircraft in flight would save the air transport companies as much as $500,000 a day in event of bad weather over a busy airport.

In another paper, "The Further Development of Fluid Mappers" by Professor A. D. Moore, the latest techniques were described and references made to the work of Hele-Shaw in England some 50 years ago. Professor Moore explained that qualitative accuracy can be built into the mapper to any degree. In the evening, an actual demonstration of the technique used in casting the slab and operating the fluid mapper was presented before several hundred interested persons. In discussion C. J. Fechheimer inquired if the fluid mapper had been used in cases of turbulent flow, which is not linear; he also referred to the work of Carter which was done about the same time as that by Hele-Shaw. Carter used the Schwarz-Christoffel theorem to analyze the field theorem.

Oil Industry Applications. In the field of oil industry applications, nine papers were presented which covered the various design and application considerations leading to the selection, use, and maintenance of motors for practically all of the major operations. The development and operation of Reda submergible pumps was described by Joe Carle. These multistage pumps with motors are designed to small diameters and in lengths of the order of 14 to 28 feet for lowering in well casings approximately five inches, six inches, or eight inches in diameter. They are used for deep well pumping.

A comprehensive report on "How the Petroleum Industry Uses Electric Power" was presented by W. H. Stueve and the data collected represented many years of experience. The paper considered the power required in each of four phases of the petroleum industry: drilling wells, producing oil, pipe lines, and refineries.

Another aspect of the subject concerned the geophysical explorations for petroleum. The paper was presented by K. E. Burg, who described various methods, including electrical engineering methods, in use in exploring for petroleum.

CHAMBER OF COMMERCE LUNCHEON

At a joint luncheon with the Oklahoma City Chamber of Commerce, which was well attended, President LeClair gave an address on the subject of "What Engineers Do for Your Business." After defining the engineer, President LeClair reviewed many of the advancements which have contributed to our high standard of living: in industry, on the farm, and in the home, as well as the economic progress. In conclusion, he stated

Induction of President LeClair into the Kiowa Indian Tribe as a leader in the electrical industry. He was given the name Chief Mau-Kodle-An-Oye which, in the words of the Kiowa Tribe, means "Man with Great Plans." Mr. LeClair is shown with Chief Saunkeah and his wife

Oklahoma City Chamber of Commerce Photo

that when you go home in the evening and turn on the light, cook, or use the faucet, refrigerator, radio, or watch television, remember what the engineers have done for you.

In an impressive ceremony, President LeClair was honored by Chief Saunkeah of the Kiowa Tribe as a leader in the great electrical industry. The toastmaster of the luncheon was Dr. John R. Abernathy and prayer was lead by the Reverend Donald N. Scott.

ENTERTAINMENT

The dinner-dance was held in the Persian Room of the Skirvin Tower Hotel on Wednesday evening. Following the dinner, songs were rendered by the Oklahoma City University Chorus, with James Nelson as director, and some of the music from the Broadway hit show "Oklahoma" was sung.

The stag smoker was held Tuesday evening with entertainment following a buffet dinner.

LADIES' ENTERTAINMENT

A special program for the visiting ladies was arranged under the chairmanship of Mrs. R. F. Danner, with Mrs. R. W. Linney as Vice-Chairman. Hostesses were present at all times at the Ladies' Headquarters to extend a cordial welcome to visitors. Trips were taken to the Oklahoma Historical Building on the State Capitol grounds. A sight-seeing tour of Oklahoma City was made, and there were visits to the Oklahoma City Country Club for brunch and the Beacon Club atop the First National Building. On Wednesday, a tour was taken to the art center; on Thursday there was a style show and buffet luncheon.

FALL GENERAL MEETING COMMITTEES

The Chairman of the General Committee was W. B. Stephenson with R. F. Danner, F. J. Meyer, and Ralph Randall as Vice-Chairmen, and M. C. Reed as Secretary. The chairmen of the Working Committees which made the arrangements were: *Publicity*, Sim Wright; *Program*, Bryce Brady; *Inspection Trips*, Otis Howard; *Sports*, J. S. Joseph; *Entertainment*, George Larason; *Ladies*, Mrs. R. F. Danner; *Finance*, J. S. Wantland; *Hotel*, R. L. Jones; and *Registration*, J. A. Taylor.

Forum of Technical Committee Chairmen Held During the Fall General Meeting

The first Forum of Technical Committee Chairmen under the expanded Technical Committee structure was held at the Skirvin Hotel in Oklahoma City, Okla., Wednesday, October 25, with President T. G. LeClair presiding. In introducing the subject, President LeClair referred to the increase in the number of technical committees and the establishment of divisional committees for closer co-ordination. He explained that last year the Board of Directors, to reduce the burden of time required for travel and extra work, decided not to have ex-officio committee members. Problems arising at the forum could be laid on the table and another meeting of this kind would perhaps be held in January.

BACKGROUND OF TECHNICAL COMMITTEE STRUCTURE

The historical background leading to the present Technical Committee structure was given by M. D. Hooven, Chairman of the Planning and Co-ordination Committee. Speaking from long experience in Institute affairs and as a Past-Chairman of the Technical Program Committee, Mr. Hooven outlined the changes which have taken place step by step from the late '20's through the war years up to the present. He referred to the Ashville Resolution, adopted by the Board of Directors in 1946, which provided for the expansion of technical activities by grouping the Technical Committees in appropriate divisions or groups with a steering committee for each group fairly compact in numbers and with provision for a 25-per cent turnover of the steering committee personnel each year. The groups met in the morning and went to the Technical Program Committee meetings in the afternoon, which worked out very well. During the last five years, the membership has increased, the number of sections has increased, and we now have over 40 technical committees in five divisions. He explained that, in view of this growth, the Board of Directors last spring found it necessary to do away with the ex-officio memberships in order to relieve the burden of chairmanships and give younger members an opportunity to serve. Several committeemen were shocked by the speed of this action. Informal discussions were held and the best suggestion that arose was the idea of the Technical Forum we now have.

OBJECTIVES UNDER DIVISIONAL OPERATION

The objectives under divisional operation were explained by M. J. Steinberg, Chairman of the Technical Advisory Committee. He stated that the idea was to permit the closest possible co-operation of technical committees having a community interest. At the same time, the plan should relieve the Board of Directors of minor details which can be delegated to different people.

With regard to apprehension that the change would tend to reduce the importance of technical committee chairmen, Mr. Steinberg explained that their importance had been enhanced by the new plan of organization and that many who had opposed the idea originally were now strong supporters. It was better to sit down and discuss matters of common interest than to conduct correspondence. He explained that under the new plan of organization the technical committee chairmen have a much greater voice in the selection of the personnel of their committees, no prerogatives have been taken away, and committees can still go directly to the Board of Directors although such a course probably would not be expedient. Under the plan of operation, each division would handle conflicts within its own group. It was conceivable that conflicts might arise between committees in different divisions, in which case the matter would be referred to the Technical Advisory Group.

In conclusion, Mr. Steinberg said that if the Institute continues to grow he believes that further decentralization will be necessary and he personally advocated divisional conventions as a possible solution.

TECHNICAL PROGRAM COMMITTEE PROBLEMS

The problems of the Technical Program Committee were outlined by C. H. Willis, Chairman. He explained that under the expanded organization the plan of operation of the Technical Program Committee and the arrangement of programs for the General Meeting had not changed. The forecasts of the divisions in regard to the number of papers to be expected during the year were found helpful in preparing the budget.

Each of the different classes of papers was reviewed by Chairman Willis, namely, the Conference paper, the ACO paper, and the *Transactions* paper. In regard to Conference papers, no financial problem was involved, but for *Transactions* papers, each recommendation posed a serious financial problem. Last year, the committee kept well within the budget allotment for papers. For the current year, a budget providing for 275 *Transactions* papers and 65 ACO papers was recommended. It was pointed out that with 25 papers on the Middle Eastern District Meeting program and 51 papers on the Fall General Meeting program there was only provision for 200 more papers during the remainder of the year. With 67 technical sessions tentatively in prospect for the Winter General Meeting, conservatism in recommending papers for the *Transactions* was suggested, the criterion being that they should have permanent record value.

Professor Willis explained that with the Fall General Meeting papers, the problem was to get them and have them reviewed during the vacation season. To meet this situation, the closing date for Fall General Meeting papers would be advanced to June, although this would not solve the problem entirely as the reviewing would still have to be done during the summer months.

PROBLEMS OF THE STANDARDS COMMITTEE

E. B. Paxton, Chairman of the Standards Committee, reviewed the history of its organizational setup, pointing out that 20 years ago standards were formulated by special subcommittees of the Standards Committee and that for about the last ten years, because of the increasing and diversified activity, this work has been performed predominantly by the Technical Committees. Contact with the Executive Committee of the Standards Committee was maintained through automatic ex-officio membership of Technical Committee Chairmen. The present organization of the Standards Committee has been studied in the light of the directive of the Board of Directors to eliminate all ex-officio memberships and this new organization proposed:

1. Executive Committee consisting of the chairman and 15 or more members appointed by the President.

2. Members as follows: Technical Committee Chairmen (or a representative named by them) who express a desire to

become members of the committee. Chairmen of Standards Co-ordinating Committees and Subcommittees of the Standards Committee. Chairmen of AIEE Delegates on other standardizing bodies or sole representatives thereon. Presidents of the United States and Canadian National Committees of the International Electrotechnical Commission. Liaison representatives.

This organization plan allows the Standards Committee to continue to perform the administrative and co-ordinating functions which are its duty in so far as standards matters are concerned.

PUBLICATION COMMITTEE PROBLEMS

In the absence of Dr. McEachron, two of the problems of the Publication Committee were explained by C. S. Rich, Editor. The first of these concerned the fact that more than twice as many papers are recommended for publication in *Electrical Engineering* than can be accommodated within the space available. For this reason, the matter of what constitutes general interest was discussed, as well as the indexes that were available from the number of orders for certain subjects in the *Proceedings* papers.

The second problem concerned a plan for divisional publications by a special subcommittee of the Publication Committee with F. R. Benedict as Chairman. An analysis of all 1949 *Transactions* papers indicated that there were not a sufficient number of papers in the fields of communication, general applications, and industry to issue quarterly publications. Another analysis of a large sample of *Proceedings* orders indicated that only 11.3 per cent of the orders received fell entirely within one division, while 21.6 per cent were in two divisions, 27.4 per cent in three divisions, 26.5 per cent in four divisions, and 13.2 per cent in all five divisions. Furthermore, to publish papers bound in quarterlies by divisions would delay some of the papers two months or more. A calendar of when the 1949 *Proceedings* papers were ready for distribution indicated that in the field of communication, for example, four papers were ready in April and five in May, which would have been delayed two months and one month respectively if a quarterly were issued in June. In the science and electronics division, one paper would have been delayed two months and seven papers one month if bound in quarterlies.

DISCUSSION

In the discussion which followed, J. E. Clem expressed hope that the 25-per cent rule for committee turnover in personnel would not be applied rigorously, because in four years the committee would lose all the men who do the work. President LeClair replied that the 25-per cent figure was not a rule but a recommendation and that, in some cases, he had added new names to a few of the committees.

Vice-President C. G. Veinott reported that he had heard complaints that the 90-day closing date was too long in advance of publication and he suggested that ways and means should be considered to get papers published in less time. He said that there were some objections to presentation by title only as he knew of engineers who had gone to meetings and were disappointed when there was no discussion. Mr. Veinott suggested that, when people in the sections cannot go to the general meetings, supplemental section meetings might be held at which the authors of general meeting papers might make trial presentations. Local members would become acquainted with the authors, and, at the same time, the presentations would be improved and added publicity would be given to the general meetings.

With respect to publications, W. G. Dow, Vice-Chairman of the Science and Electronics Division, drew attention to the need for a more highly technical type of publication which would go automatically to perhaps 10 per cent of the membership, those doing graduate work and those who have graduated recently and taken the electronics option.

Walter Richter drew attention to the publications of the Institution of Electrical Engineers of England, pointing out that they publish material in three parts: 1. general, 2. power engineering, and 3. radio and communication engineering, and that seemed to him a very satisfactory system.

The Chairman of the Technical Advisory Committee, M. J. Steinberg, explained that as a member of the Institute he could receive a preprint, *Electrical Engineering*, the *Proceedings*, and the *Transactions*, and that he did not know of any other organization which gave more for dues than the AIEE.

The Forum voted to rotate the chairmanship among those on the panel in alphabetical order. M. D. Hooven presided during the remainder of the meeting. E. B. Paxton would be Chairman of the next meeting, and he was instructed to arrange the agenda and correspond with the other chairmen on the panel.

The remainder of the meeting was taken up with a lengthy discussion as to the type of meeting, national in character, which might be arranged for Chicago, Ill., in the fall of 1952. The American Society of Civil Engineers has invited the Institute to take part in a centennial of engineering at that time. In the absence of specific dates and with plans for the Fall General Meeting to be held in New Orleans that year and for a meeting of the Great Lakes District in Toledo, October 28–30 of the same year, a difficult problem was posed. As several of the divisional committees and the Technical Advisory Committee were meeting later in the week, it was agreed that more specific information in respect to the type of meeting which might be arranged would be sent to the Chicago Section at a later date.

Nucleonic and Medical Papers Presented at Electronic Instrumentation Conference

The third annual joint Conference on Electronic Instrumentation in Nucleonics and Medicine, sponsored by the AIEE and the Institute of Radio Engineers, was held October 23, 24, and 25 at the Park Sheraton Hotel in New York, N. Y., with 653 people attending. It is not planned to publish the papers in pamphlet form.

EFFECTS OF ATOMIC WEAPONS

A highlight of the conference was a round-table discussion on the subject, "Effects of Atomic Weapons." This session was held the evening of October 24, and Dr. W. R. G. Baker, General Electric Company, was chairman. Members of the panel were Dr. William Bale, University of Rochester (N. Y.); Dr. H. L. Bowman, Drexel Institute of Technology, Philadelphia, Pa., and Consultant on Civil Defense to the Atomic Energy Commission (AEC); Brigadier General J. P. Cooney, AEC; Dr. Herbert Scoville, Armed Forces Special Weapons Project; and Dr. Fred Reines, Los Alamos Scientific Laboratory.

Dr. Baker took the point of view of the man on the street and presented questions to the panel in which this mythical man would be interested, such as what would he do when he is warned of an atomic attack; where would he go; what kind of an alert would he get; what are some of the after-effects; what cities are likely to be attacked; what are the authorities doing?

Each panel member answered one question. General Cooney discussed the evacuation of casualties and their care. He stressed the fact that education and training for the layman are the big problems, but they are not insurmountable.

Dr. Bowman described the effects of an atomic bomb explosion in an American city, which he thought would fare little better than the Japanese cities did in World War II. Dr. Reines dealt with the effects of a bomb explosion on human beings, stressing that secondary burns are the main hazards. Dr. Scoville stated that the large casualties in Japan were caused by the lack of warning so that the populace was subjected to the thermal radiations from the bomb explosions. This type of radiation can be guarded against by ordinary clothing and also by taking shelter from the direct effects of the blast. He brought out that it is possible to work within contaminated areas for short periods of time if the amount of radiation is known, and this can be measured easily.

Dr. Bale spoke about the necessity for dependable radiation detection instruments for proper radiation surveys so that rescuers can work within the bombed area safely. Such instruments, which do not have to be too accurate but must be dependable, are available today.

After these talks, the meeting was thrown open to questions from the audience, which the panel members answered. Most of the questions pertained to what effects might be expected on people within bombed areas and how casualties could be kept low.

NUCLEONIC INSTRUMENTS MANUFACTURERS GROUP

At a luncheon meeting on October 24, the Nucleonic Instrument Manufacturers Group, comprising the exhibitors at the Conference, heard Dr. N. H. Woodruff of the Isotopes Division, Atomic Energy Commission, propose a plan whereby a pool of nucleonic instruments be formed, a portion of which would be loaned to colleges where

personnel would be trained in the use of radioisotopes. Up to this time the AEC has given 17 courses at Oak Ridge where 544 people have been trained at a cost to the Government of $532 each. Four colleges in different parts of the country have been asked if they would give courses, and while the answers were in the affirmative, as they saw the need for training, each would require outside help, their greatest need being instruments. The group decided to appoint a committee to investigate Dr. Woodruff's proposal.

J. A. Schoke, Nuclear Instrument and Chemical Corporation, was elected chairman of the group for 1950–51. L. W. Cronkhite, president of the Atomic Instrument Company, the retiring chairman, D. W. Atchley, and Mr. Schoke are three of the 5-man General Planning Committee. The remaining members of the committee will be appointed later.

Exhibits of nucleonic apparatus, instruments, and components were shown by 20 manufacturers of this type of equipment. Radiation detectors of all types from Geiger counters to small ionization chambers and film badges were featured in the exhibits. One popular demonstration had a miniature traffic light connected to an oscilloscope and a push button in such a way that the observer could time his reaction to the light's changing from green to red.

TECHNICAL PROGRAM

The technical program was divided into three parts: the first day papers on subjects in the nonnucleonic phases of electronics in medicine were featured; the second day was devoted to nucleonics in medicine; and the last day covered nucleonic development in industry and government laboratories.

First day's sessions. The first day's sessions, which were presided over by Dr. Joe Howland of the Atomic Energy Project at the University of Rochester (N. Y.), were opened by the presentation by W. O. Fenn of the paper "The Needs of Physiology and Medicine for Better Instrumentation for the Measurement of Respiratory Gases," which was prepared by Mr. Fenn and R. C. Fowler, both of the University of Rochester. The need of having easily operated portable instruments for obtaining continuous and instantaneous records of changes in the composition of the gas during a single exhalation was stressed in this paper.

"The Analysis of Respiratory Gases with Mass Spectrometer" was written by F. A. Hitchcock and R. W. Stacy of Ohio State University, Columbus, Ohio, and presented by Mr. Hitchcock. To force the residual air from the lungs the subject is exposed to an explosion. The spectrometer used in this study was a permanent-magnet instrument with a Philips-type tantalum anode and used 35 45-volt batteries as a power supply. It was accurate to one millimeter of partial pressure of gases, and could be made more accurate with a sacrifice in reliability.

"Analysis of Respired Air of the Rat in the Mass Spectrometer," written by A. W. Pratt, Bernard Burr, Murray Eden, and Egon Lorenz, all of the National Institute of Health, Bethesda, Md., was presented by Mr. Pratt. This experiment was used as a nutritional indicator, because the spectrometer indicated the CO_2 resulting from the oxygen in the food being metabolized.

E. D. Palmes of New York University, Bellevue Medical Center, New York, N. Y., discussed the "Application of an Infrared Gas Analyzer to Problems of Sweat Physiology." The apparatus could be used to give a continuous and almost instantaneous record of the evaporative rate from a whole body or from small skin areas.

The process of "The Measurement of Oxygen in Gases by Paramagnetism" has been studied by A. O. Beckman of South Pasadena, Calif. Because oxygen has a high paramagnetic susceptibility it gives a direct measure of oxygen partial pressure with only minor corrections for the susceptibilities of background gases.

The afternoon session of this group of papers was opened with the description of "An Ultrasonic Method for Outlining the Cerebral Ventricles." This paper was prepared by H. T. Ballantine and G. D. Ludwig of Massachusetts General Hospital, Boston, Mass.; and R. H. Bolt and T. F. Hueter of the Acoustics Laboratory of Massachusetts Institute of Technology, Cambridge, Mass. It is possible to use ultrasonics to explore the cerebral ventricles because the white matter in the brain has an attenuation of from two to four decibels per centimeter of tissue, while the ventricle liquid has only an attenuation of 0.01 decibel per centimeter. At present the power transmitted to the subject is one watt per square centimeter, which is harmless. A facsimile printer is used to present the picture, which is made up of 300 lines and 20 columns.

"The Medical Physics of External Localization of Brain Tumors with Radioactive Di-iodo^{131}-fluorescein" by T. Fields, G. V. LeRoy, and Moses Ashkenazy, Veteran's Hospital, Hines, Ill., was presented by Mr. Fields. He discussed injection procedures, scanning methods, electronic recording devices, and radiation detection methods.

In the paper, "The Use of Isotopes in the Measurement of Body Fluids," J. L. Nickerson, Columbia University, New York, N. Y., told how a radioactive substance was injected into the body and samples of fluid taken so that the dilution of the substance could be measured.

"Refined Sectioning Techniques for the Electron Microscope," written by James Hillier, Radio Corporation of America Laboratories, Princeton, N. J., and Sloan-Kettering Institute for Cancer Research, New York, N. Y., and read by S. G. Ellis, described the contributions made to the field of preparing specimens for study with an electron microscope.

Second day's sessions. The second day's sessions, which centered on nucleonics in medicine, were presided over by Dr. Ward Davidson, Consolidated Edison Company of New York, Inc., New York, N. Y. First paper of this group was "General Survey of Instrumentation for Health Physics," by H. M. Parker, General Electric Company, Hanford Works, Richland, Washington. The difficulties of realizing fundamental conditions in the laboratory and the impracticability of so doing in field measurements was described in this survey.

"Calibration of Radiation Detection Instruments," by L. D. Marinelli, Argonne National Laboratory, Chicago, Ill., described some of the standard instruments and experimental setups for calibrating radiation-measuring instruments and their underlying theory.

W. T. Ham, Jr., Medical College of Virginia, Richmond, Va., in his paper "A Calorimetric Method of Measuring High X-Ray Intensities," told how the differential temperature rise in a column of flowing water exposed to radiation from a 50-kv 50-milliampere beryllium window X-ray tube has been used to determine the energy absorption.

In a discussion it was brought out that X-ray radiation measurements from television picture tubes were made by the Joint Electron Tube Engineering Council for the Radio Manufacturers Association, and these tests showed there was no hazard to the viewing public.

In the afternoon session G. S. Hurst and R. H. Ritchie, Oak Ridge National Laboratory, Oak Ridge, Tenn., in their paper on "Fast Neutron Dosimetry and Related Problems," described a proportional counter, which uses an electronic circuit which discriminates against gamma pulses from the chamber and integrates the recoil proton pulses according to their height. Then the count-rate reading obtained is proportional to the fast neutron dosage received by the chamber.

A paper on "New Medical Applications of Tracers" was read by A. H. Holland of the Amour Laboratory, Chicago, Ill. E. C. Pollard, Yale University, New Haven, Conn., gave a progress report of his studies of "Physics and Viruses." In his attempts to determine the exact nature of viruses Dr. Pollard has used a deuteron beam from a cyclotron. He stated for the benefit of instrument manufacturers that a hydrogen arc was badly needed in his experiments.

Third day's sessions. Dr. Urner Liddel, Office of Naval Research, Washington, D. C., presided over the closing sessions. The first paper was by D. L. Collins, Victoreen Instrument Company, Cleveland, Ohio; D. Atchley, Tracerlab, Boston, Mass., and J. A. Schoke, Nuclear Instrument and Chemical Corporation, Chicago, Ill.; it described the "Manufacture and Quality Control of Geiger Mueller Tubes."

A 600-volt boron-line counter tube and its characteristics was described in "Boron-Lined Neutron Counters" by W. W. Schultz and R. M. Lichtenstein of General Electric Company, Schenectady, N. Y. The effect of filling pressure and anode wire diameter on the operating voltage was discussed.

W. S. Macdonald and E. W. Jervis, Jr., of the W. S. Macdonald Company, Cambridge, Mass., spoke on "Design of a Commercial Scintillation Counter" based on the following features: (1) A versatile arrangement for the phosphors or crystals; (2) A method of transmitting the light from the crystal to the photomultiplier tubes; (3) The reduction of background counts due to the dark-current noise of photomultiplier tubes; (4) Over-all stability and freedom from variations due to line voltage changes; and (5) Elimination of spurious counts caused by external noise sources such as X-ray or diathermy equipment, which might be encountered through the use of this instrument in a hospital.

In the paper "Testing Photomultipliers for Scintillation Counting," R. W. Engstrom, Radio Corporation of America Laboratories, Princeton, N. J., discussed the ad-

vantages of the end-on construction and transmission-type photocathode of multiplier phototube type *5819* for scintillation counting applications and described some of the production tests used for controlling the characteristics of this tube.

The afternoon session opened with an enumeration of the applications of scintillation counters by George Cowper, Chalk River, Ontario, Canada, in the paper "Scintillation Counter Instrumentation." Alpha particle detectors for the location of radioactive contamination and for the measurement of low specific activity biological samples use a zinc sulphide screen as the detecting element. The contamination detector has a background counting rate of only a few per minute and the low-activity counter makes between six and eight counts per hour.

"Recent Advances in Electron Techniques in Canada," by N. F. Moody, G. J. R. MacLusky, and M. O. Deighton, Chalk River, Ontario, Canada, told how the increasing application of scintillation counters has stimulated the development, for the millimicrosecond time scale, of basic circuit elements such as pulse amplifiers, pulse height discriminators, trigger circuits, time-base generators, and coincidence mixers. It is expected that these techniques will find important applications in other fields.

J. A. Hipple, National Bureau of Standards, Washington, D. C., described "Recent Developments in Mass Spectrometry." Improvements in this field have resulted from the expanding application to routine analytical problems. The accelerated use of this technique in fundamental research has resulted in the construction of instruments based on entirely new principles.

COMMITTEE CHAIRMEN

Committee chairmen for the conference were: G. W. Dunlap, *Planning;* E. Grazda, *Publicity;* J. H. Mulligan, Jr., *Finance;* David Langmuir, *Technical Program;* R. L. Schoenfeld, *Local Arrangements;* and L. W. Cronkhite, *Exhibitors.*

High-Frequency Measurements Conference Planned for January

Arrangements for the second High-Frequency Measurements Conference sponsored jointly by the AIEE, the Institute of Radio Engineers (IRE), and the National Bureau of Standards are being completed. The conference is scheduled for January 10 to 12, 1951, and is the first scientific gathering of national scope to be brought to Washington in 1951 in celebration of the Semicentennial of the National Bureau of Standards. The introductory address will be delivered by Dr. Edward U. Condon, Director of the Bureau.

A particularly complete treatment of the present status and future trends of development in the standardization of frequency and time will be a feature of the first session. Recent data on the performance of 100-kc quartz crystal standards will be disclosed and the promising possibilities of a new type of crystal operating in the 5- to 10-megacycle region will be outlined. A survey of atomic time standards will accompany current reports from several laboratories working in this field.

Precise coaxial line measurements, sweep methods, and dielectric constant determinations will be discussed in the Impedance session along with a scheme for rapid Q measurements at very high frequencies. In the Power and Attenuation session several authors will deal with various methods of absolute and relative power measurements at microwave frequencies. Attenuator corrections, millidecibel determinations, and microwave oscillography also will be discussed.

The final session on Measurements of Transmission and Reception will encompass such diverse subjects as simulated infinite conducting planes and millimeter band techniques. A report from Great Britain on field strength meters will be followed by papers on radio relay, traveling wave tube, and piezo crystal measurements.

Three demonstration lectures to be staged Thursday evening, January 11, will highlight the conference. These will be held in the Department of the Interior Auditorium and will constitute the Annual Joint Meeting of the local AIEE and IRE Sections.

The National Bureau of Standards will display a microwave spectroscope in operation with the aid of a projection oscilloscope. The Bureau also will demonstrate a recording microwave refractometer adapted for atmospheric measurements. An outstanding speaker of the evening will be Dr. Winston E. Kock of Bell Telephone Laboratories, who will present a new and striking demonstration of the parallel behavior of microwaves and centimeter wave length sound waves.

Inspection trips to the National Bureau of Standards and the Naval Ordnance and the Naval Research Laboratories have been arranged. Of particular interest to some will be a trip to the United States Naval Observatory where correlation of electronic time standards with celestial observations by means of the photographic zenith tube will be discussed.

The Conference is under the general direction of Professor Ernst Weber of the Microwave Research Institute of the Polytechnic Institute of Brooklyn (N. Y.), as Chairman of the Joint AIEE—IRE Committee on High-Frequency Measurements.

The registration fee is $2.00 if paid in advance or $2.50 at the conference. Advance registrations may be mailed to Mr. W. F. Snyder, National Bureau of Standards, Washington 25, D. C.

AIEE-ASME Preferred Standard for Steam Turbine-Generators

The Joint AIEE-American Society of Mechanical Engineers (ASME) Committee on Steam Turbine-Generators has completed a review of the prevailing standards. This revision has been approved by the AIEE and ASME.

The revision consists primarily of the addition of a 90,000-kw turbine generator to the group of preferred standard machines. This means that the standards now cover seven machines: an 11,500-kw air-cooled machine, and 15,000-kw, 20,000-kw, 30,000-kw, 40,000-kw, 60,000-kw, and 90,000-kw hydrogen-cooled units. The new 90,000-kw turbine will be available either as a regenerative cycle machine or a reheat cycle machine.

The new generator is rated at 0.5 pound per square inch gauge hydrogen pressure with 15-per cent additional kilovolt-ampere capability above generator rating provided by increasing the hydrogen preasure to 15 pounds per square inch gauge similar to the other hydrogen-cooled machines. In addition, it will be designed for operation at 30 pounds per square inch gauge under which condition the generator capability will be 25 per cent above its rating at 0.5 pound per square inch gauge. The excitation voltage will be 375 volts with an option of 250 volts. The generator voltage will be 13.8 or 14.4 kv. The characteristics of the remaining machines have not been changed from the previous edition of the Standard except for the elimination of 11.5 kv as a standard generator voltage. This change was found desirable because of the very few machines purchased with this voltage.

The revised AIEE Standards, published in one pamphlet, now available are:

Number 601—Preferred Standards for Large 3,600-rpm 3-Phase 60-Cycle Condensing Steam Turbine-Generators (Larger than 10,000-kw Rated Capacity).

Number 602—Standard Specification Data for Generators for Large 3,600-rpm 3-Phase 60-Cycle Condensing Steam Turbine-Generators (Larger than 10,000-kw Rated Capacity).

Price, $0.60 per copy (50 per cent discount to AIEE members for single copies).

Chicago and Minneapolis Sections Hear Talk by P. L. Bellaschi

"Power Transmission at Extra-High Voltages—Developments and Trends" was the topic of discussion at recent meetings of the Chicago and Minneapolis Sections, given by Peter L. Bellaschi, consulting engineer of Portland, Oreg. This talk covers current developments and specific projects in the United States and abroad in the field of power transmission at very high voltages, with especial reference to the basic economic aspects and major engineering considerations of the problem. Sound films of the Swedish 380-kv system now under construction and of the Alfta 230-kv series capacitor in operation well over one year were presented.

To date, Mr. Bellaschi has presented this address before ten other sections.

COMMITTEE ACTIVITIES

Editor's Note: This department has been created for the convenience of the various AIEE technical committees and will include brief news reports of committee activities. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

Communication Division

Committee on Television and Aural Broadcasting Systems. (*J. B. Coleman, Chairman; I. J. Kaar, Vice-Chairman; W. L. Lawrence, Secretary.*) The first meeting of this new committee was held on September 15. This

committee combines the scopes for the former separate committees on Aural Broadcasting Systems and Television Broadcasting Systems. Initial work is directed toward arranging for at least one technical session at the Winter General Meeting and preliminary plans for technical sessions at later general meetings. A report reviewing the important items of progress in the field of broadcasting during 1950 is being prepared for publication in *Electrical Engineering*. A review was made of standards work and, in view of the present adequate coverage in this field by other groups, the committee decided to undertake no new work on Standards at this time.

Committee on Telegraph Systems. (*I. S. Coggeshall, Chairman; J. A. Duncan, Jr., Vice-Chairman; E. C. Chamberlin, Secretary.*) This committee is planning a well-rounded technical session on telegraph systems for the coming Winter General Meeting in New York City, and a meeting will be held then for the purpose of lining up future papers and reviewing developments since the last meeting.

General Applications Division

Committee on Domestic and Commercial Applications. (*Carl F. Scott, Chairman; T. H. Cline, Vice-Chairman.*) L. R. Emmert has been appointed Chairman of a newly formed subcommittee, which will study problems of farm electrification. Mr. Emmert attended the National Farm Electrification Conference, held in St. Louis, Mo., October 15, as a representative of this committee. He also acted as an AIEE delegate and member of the Conference Steering Committee. Mr. L. N. Roberson is an alternate and will be Vice-Chairman of the new subcommittee.

The Subcommittee on Heat Pumps and Electric Heating of Houses, with T. C. Johnson as Chairman for the eastern region, is actively engaged in working up a technical session on these topics for the Winter General Meeting. The interest shown in this subject previously convinced the subcommittee that a considerable number of members would want to follow the progress made during the past year. The subcommittee for the Pacific Coast, with J. C. Beckett as Chairman, is planning a technical session or conference on these topics for the Pacific General Meeting in Portland next August.

The Subcommittee on Domestic Appliances (C. R. Reid, Chairman) is planning to promote another technical conference during the early part of 1951 because of the success of the Special Technical Conference on this subject, held in Cleveland last June.

Committee on Air Transportation. (*W. V. Boughton, Chairman; D. E. Fritz, Vice-Chairman; W. L. Berry, Secretary.*) At a meeting held on October 2 the committee discussed the Boeing Airplane Company's proposed study on "Aircraft Electric Generating System D-C Transients" and agreed to refer the study to the Aircraft Electrical Rotating Machinery Subcommittee for action. Methods of co-ordinating the activities of the committee with those of the Armed Services, Aircraft Industries Association, and Society of Automotive Engineers were discussed and a committee was appointed to develop means for such co-ordination.

Subcommittee reports showed much activity during the past year. The Aircraft Electrical Rotating Machinery Subcommittee is ready to issue a revised tentative test code, and the Aircraft Electrical Systems Subcommittee is developing methods and evaluation procedures for maximum short-circuit current and system stability tests.

The committee will hold a meeting during the Pacific General Meeting at Portland, Oregon, next August.

Industry Division

Committee on Feedback Control Systems. (*S. W. Herwald, Chairman; F. E. Crever, Vice-Chairman; A. G. Kegel, Secretary.*) The large number of papers submitted on various phases of feedback control systems is evidence of the wide interest and increasing range of application of the techniques developed within comparatively recent times. The committee will continue to concern itself with evaluating the papers submitted and recommending for publication those which appear to make a contribution to the advancement of the science.

The Subcommittee on Terminology and Nomenclature, having reported on its standardized symbols (*EE, June '50, p 566*), is extending its work in an effort to agree upon definitions of terms.

Recognizing the fact that the human operator plays a significant part in many feedback control systems, the committee hopes in the near future to schedule a session in which the behavior of "psychobiological" systems is discussed.

Power Division

Project Committee on Electronic Relay Applications of Committee on Relays. (*A. J. McConnell, Chairman.*) Performance data is being gathered by this subcommittee on an electronic phase distance relay which has been in service for three months on an 88-kv 50-mile line with loop and taps. About 30 faults per year occur on this line. The relay is connected for indication only—no tripping. Several interesting comments have been made on the pros and cons of electronic relays. It has been mentioned that perhaps some day electronic relays would solve some of the problems which mechanical relays have been unable to solve, and, therefore, experiences with electronic relays should be encouraged even if they do the same job today as a mechanical relay.

Working Group on Transient Performance of Capacitor Potential Devices of Committee on Relays. (*T. R. Halman, Chairman.*) It was reported that the transient response was best with high-power factor burdens nearly equal to the rating of the device. Further study of the results of tests already completed will be made. Tests with actual relays were requested of several companies, also tests of dropping voltage to 10 per cent of normal. It has also been suggested that the Relays Committee have tests made on relays to determine their performance under conditions produced when used with potential devices. The problem is further complicated by the fact that the performance of distance relays is affected by harmonics, both in magnitude and phase.

Committee on Carrier Current. (*S. C. Bartlett, Chairman; C. W. Boadway, Vice-Chairman (East); R. H. Miller, Vice-Chairman (West); E. W. Kenefake, Secretary.*) At a recent Institute meeting this committee, in an attempt to stimulate wider interest in its work, held an all-day meeting, giving particular attention to acquainting the West Coast people with their activities. At one of the sessions sponsored by this committee, papers were presented covering means of obtaining a greater utilization of the limited spectrum which is being required today to handle the increasing burden of telemetering, supervisory control, load control, relaying, and the various other duties which are placed upon the communications systems as we proceed in the direction of system expansion and automatization. The discussion on other papers presented, covering test methods and instruments and new techniques for tuning line traps, such as for broad-band applications, showed that the information was well received and more desired.

Science and Electronics Division

Committee on Therapeutics. (*H. D. Moreland, Chairman; S. Reid Warren, Jr., Vice-Chairman; Scott W. Smith, Secretary.*) Reactivation of this committee was accomplished by a meeting held on September 6, at which time the overlapping interests, scope, and basic material of the Committee on Therapeutics and the Joint Subcommittee on Electrical Aids to Medicine were discussed. It has been recommended that these two committees be combined into a single committee to be known as the Committee on the Uses of Electricity in Medicine and Biology. A recommended scope for the proposed committee has been prepared, which is as follows: "Electrical techniques that are used in medical and biological research, diagnosis, and therapeutics. The committee is concerned particularly with the intercommunication of problems, and their solutions, between electrical engineers on the one hand and physicians and biologists on the other. Therefore, the committee usually plans papers and programs jointly with other AIEE committees that are assigned specific devices such as X-ray tubes and control equipment, infrared and ultraviolet sources, nucleonic measuring equipment, protective devices, and so forth. The committee may need the aid of physician- and biologist-consultants who are interested in interscientific collaboration."

A subcommittee of the Committee on Therapeutics was established for the purpose of promoting technical papers relating to the electromedical industry.

Committee on Instruments and Measurements. (*W. R. Clark, Chairman; J. E. Hobson, Vice-Chairman (West); J. H. Miller, Vice-Chairman (East); J. G. Reid, Jr., Secretary; W. S. Pritchett, Secretary (West).*)

The Master Test Code for Temperature Measurements of Electric Apparatus has been accepted as an AIEE Standard, as of August 1950. This test code, AIEE Standard Number *551*, was composed by a subcommittee of this committee, of which L.A. Burckmyer, Jr., was Chairman.

Committee on Nucleonics. (*W. F. Davidson, Chairman; G. W. Dunlap, Vice-Chairman; W. E. Barbour, Jr., Secretary*). New chairmen have recently been appointed for the three subcommittees and for the Joint Subcommittee on Nucleonic Instruments (*EE, Oct '50, p 944*).

One major activity of the Committee has been the Third Annual Joint AIEE-IRE Conference on Electronic Instrumentation in Nucleonics and Medicine. For the AIEE, the sponsoring groups include the Committees on Nucleonics, Electronics, and Instruments and Measurements, and the Joint Subcommittees on Nucleonic Instrumentation and Electrical Aids to Medicine. This activity, now in its third year, has reached a popularity that seems to assure its continued existence for some time to come.

The committee plans to sponsor a conference session at the Winter General Meeting in New York. Other conferences will be held at the North Eastern District Meeting in May, Summer General Meeting in June, and the Pacific General Meeting in August. One technical session is contemplated in connection with the Summer General Meeting in Toronto, Canada, at which time it is confidentally expected that there will be important contributions from Canadian workers in the field of nucleonics.

AIEE PERSONALITIES.....

Reinhold Rüdenberg (M '38, F '50), Gordon McKay Professor of Electrical Engineering, Harvard University, Cambridge, Mass., recently received the gold Cedergren Medal and Scroll for 1949, the Swedish award for meritorious work in the field of electrical engineering. It is awarded every five years to the most deserving in the arts and sciences of electricity by the Royal Governors for the Universities of Technology in Sweden. Dr. Rüdenberg is the eighth recipient of this honor. He came to Harvard in 1939 from the General Electric Company, London, England, to which he had been a consulting engineer. Born in Hannover, Germany, on February 4, 1883, he received a diploma in Engineering and a Doctor of Engineering degree from Hannover Institute of Technology. He was an honorary professor at the Institute of Technology in Charlottenburg while he worked as Chief Electrical Engineer of Siemens-Schuckertwerke in Berlin from 1923 to 1936. In 1912, Dr. Rüdenberg was awarded the Montefiore Prize of Liége University in Belgium for his work on commutator machinery. In 1946 he received an Honor Award Medallion from the Stevens Institute of Technology for his work in electron optics. He is the inventor of the electron microscope, which has played an important part in modern medical and industrial research. Dr. Rüdenberg is the author of a number of books on electrical engineering and many technical papers. He is also a fellow of the American Academy of Arts and Sciences and a member of Sigma Xi.

L. R. Ludwig (A '28, M '41), Manager, Westinghouse Motor and Control Division, Buffalo, N. Y., has been appointed assistant to the vice-president. Mr. Ludwig graduated from the University of Illinois in 1925 with the degree of Bachelor of Science in Electrical Engineering. In 1929 and 1930 he studied at the University of Berlin, Germany, as recipient of the first Lamme Memorial Scholarship. Mr. Ludwig joined Westinghouse in 1925 and has been associated with them continuously since that time. Working with Dr. Joseph Slepian, he helped to develop the ignitron tube which changes alternating current to direct current. Mr. Ludwig became manager of the company's Circuit Breaker and Protective Devices Department in September 1940 and was named manager of the Motor Division in 1943. He was placed in charge of operations at the company's Buffalo Works when it opened in 1946. Mr. Ludwig has written many technical papers and holds several patents. He served the Institute on the Protective Devices Committee from 1938 to 1944.

L. C. Holmes (A '31, M '43), Associate Director of Research, Stromberg-Carlson Company, Rochester, N. Y., has been named Director of Research. Mr. Holmes was born in Brookfield, N. Y., on April 10, 1904. He is a graduate of Rensselaer Polytechnic Institute, Troy, N. Y., where he taught for 18 years following his graduation in 1925. He holds the degrees of Electrical Engineering and Master of Electrical Engineering. Previous to his appointment as Associate Director earlier this year, Mr. Holmes had held the post of senior electrical engineer in the Research Laboratory since joining the firm in 1943. He is well known in the field of magnetic sound recording. Mr. Holmes has served the Institute as a member of the following committees: Communications (1947–49); Special Communications Applications (1949–51); and is chairman of the Rochester (N. Y.) Section Membership Committee. Mr. Holmes is a fellow of the Institute of Radio Engineers, a member of the Acoustical Society of America, and Sigma Xi.

J. M. Wallace (A '41, M '48), Engineering Manager, Switchgear Distribution Apparatus Department, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been appointed manager of the Switchgear Distribution Apparatus Department. Mr. Wallace was graduated from the University of Pittsburgh in 1935, with a Bachelor of Science degree in physics and engineering. He joined Westinghouse shortly after graduation and was assigned to the company's high-power laboratory, and later was transferred to the Switchgear Division. In 1945 Mr. Wallace was named the nation's outstanding young electrical engineer by Eta Kappa Nu. Early in 1949 he was appointed engineering manager of the Switchgear Distribution Apparatus Department. **H. H. Fahnoe** (A '35, M '49), Section Manager, Switchgear Distribution Apparatus Department, succeeds Mr. Wallace as engineering manager of the department. Mr. Fahnoe was granted the degree of Electrical Engineer by Cornell University in 1934, and joined Westinghouse the next year. He is a member of the Pennsylvania Society of Professional Engineers.

C. E. Scholz (M '26), Vice-President, Engineering and Plant Department, Mackay Radio and Telegraph Company, New York, N. Y., has been appointed Vice-President and Chief Engineer of All America Cables and Radio, Inc., and The Commercial Cable Company of American Cable and Radio Corporation. Mr. Scholz graduated from Stanford University, receiving the degree of Bachelor of Arts in Mechanical Engineering. Mr. Scholz has been associated with the International Telephone and Telegraph Corporation and its affiliated companies since May 1917, when he joined the Federal Telegraph Company as an engineer. He advanced to the position of chief engineer, and in 1945 became Vice-President and Director of Mackay Radio and Telegraph Co. Mr. Scholz is a member of the Institute of Radio Engineers.

H. L. Durgin (M '40), Vice-President and Chief Engineer, Central Vermont Public Service Corporation, Rutland, has been elected Executive Vice-President. He has been employed by Central Vermont Public Service Corporation since its organization in 1929 and has been an officer of the company for the last seven years. He served as electrical engineer from 1929 to 1934; as chief engineer from 1934 to 1943; and became vice-president and chief engineer in 1943. He will continue to fulfill the duties of chief engineer.

C. R. Benson (A '31), Assistant Manager, Distribution Transformer Sales Division, General Electric Company, Oakland, Calif., has been appointed manager of sales of General Electric's Oakland Transformer plant. Mr. Benson joined General Electric in 1926 following his graduation from Stanford University with a degree in Electrical Engineering. In 1927, he was assigned to the Central Station Department and two years later he was assigned to the General Electric San Francisco office as meter and transformer specialist. Mr. Benson was transferred in 1939 to the Oakland works, where he was commercial representative of the Transformer Division before being named assistant manager.

S. K. Fosholt (A '39, M '45). Chief Engineer, Stanley Engineering Company, Muscatine, Iowa, has been taken into the firm as a partner. Mr. Fosholt graduated in 1938 from Iowa State College with a Bachelor of

Science degree in Electrical Engineering. Since then he has been employed by the Stanley Engineering Company continuously except for a one-year period during the war when he served as an instructor in the Naval Training School (Electrical) at Iowa State College. Mr. Fosholt is also a member of The American Society of Mechanical Engineers.

W. J. Brockhouse, Jr. (A '49), Sales Engineer, J. E. Murray and Company, Kansas City, Mo., and **R. E. Martin** (A '50), Application Engineer, S&C Electric Company, Chicago, Ill., have been appointed sales engineers for the West Central States (Nebraska, Kansas, Oklahoma, and the western counties of Iowa and Missouri). Prior to his experience with J. E. Murray, Mr. Brockhouse had been associated with Kaiser Aluminum and Chemical Sales, Inc. Mr. Martin has been associated with S&C Electric Company since 1948.

H. W. Graybill (M '50), New Holland Machine Company, New Holland, Pa., has joined the staff of the Railway and Industrial Engineering Company, Greensburg, Pa., as a design engineer. Mr. Graybill graduated from Drexel Institute of Technology in 1937 with a Bachelor of Science degree in Electrical Engineering. His previous experience includes association with Westinghouse Electric Corporation in the Switchgear Engineering Department.

D. H. McIntosh (A '43, M '50), Application Engineer, Electrical Department, and **K. V. Knudsen** (A '50), Engineer, both of Allis-Chalmers Manufacturing Company, Milwaukee, Wis., have been named as sales representatives to Allis-Chalmers general machinery division offices in Chicago. **D. H. Verhein** (A '49), Student Trainee, has been named as sales representative to Allis-Chalmers general machinery division office in Milwaukee, Wis.

G. C. Quinn (A '46), Industrial Press Department, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has been appointed supervisor of industrial press relations. Mr. Quinn received a degree in Electrical Engineering from Marquette University in 1941. He has been associated with Allis-Chalmers for eleven years and since 1945 he has been editor of the Allis-Chalmers Electrical Review. Mr. Quinn is serving the Institute as a member of the National Publication Committee.

J. W. Thomas (A '36, M '45), Assistant Plant Engineer, Potomac Electric Power Company, Washington, D. C., has been appointed Plant Engineer in charge of the Potomac Electric Power Company's Buzzard Point Power Plant. After graduating from The Johns Hopkins University with a Bachelor of Science degree in Electrical Engineering, Mr. Thomas worked for six years for the Consolidated Gas Electric Light and Power Company of Baltimore, Md. In 1933, he was employed by Potomac Electric Power Company as a watch engineer, and he has been the assistant plant engineer at the Buzzard Point Plant since 1949.

R. J. Coe (M '48), Assistant Chief Engineer, New England Power Service Company, Boston, Mass., has been appointed executive director of the Committee on Ordnance of the Research and Development Board, Department of Defense. Mr. Coe graduated from Cornell University in 1925, and was with the General Electric Company for a short period before he became associated with the New England Power Service Company.

W. F. Young (M '36), Vice-President, Lapp Insulator Company, Leroy, N. Y., has been appointed Assistant to the President of Locke Incorporated, Baltimore, Md. Mr. Young was graduated from the University of Pittsburgh with a degree in Electrical Engineering in 1920. Before joining Lapp Insulator Company in 1927, he was associated with the Pennsylvania Railroad and the Dusquesne Light Company.

A. W. Eichmann (M '46), Procurement Engineer, The Glenn L. Martin Company, Baltimore, Md., has been appointed to the Sales Engineering staff of Lear, Inc., Teterboro, N. J. Mr. Eichmann is a Yale graduate in the field of electrical engineering. Prior to his association with The Glenn L. Martin Company Mr. Eichmann was head of the Electrical Test Department for General Electric Company.

C. F. Herbold (A '33, M '41), Manager, Industrial Relations Department, Westinghouse Electric Corporation, Lima, Ohio, has been appointed to the position of director of manufacturing planning. Mr. Herbold was graduated in 1932 from Case Institute of Technology with a Bachelor of Science degree in Electrical Engineering. He joined Westinghouse in 1933, and after serving the company in various capacities he was appointed manager of Industrial Relations in 1941.

Ernst Ohnell, Jr. (A '38), Export Manager, Sales Department, The Kerite Company, New York, N. Y., has been named manager of power and industrial sales in the Eastern United States. He will also continue his duties as export manager, a position which he has held since 1943. **L. W. Eighmy** (A '36), Sales Engineer, has been appointed to assist Mr. Ohnell in all his duties. Before joining the Kerite Company in 1936, Mr. Eighmy was associated with the American Forge Company, Reading Iron Company, and the Buffalo-Niagara Electric Company.

F. M. Scott (A '41, M '50), application engineer, Motor and Generator Section, Electrical Department, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has been named a sales representative in the company's Chicago, Ill., district office. Mr. Scott has been associated with Allis-Chalmers since 1940.

Jack Hause (A '35, M '48), Locomotive and Car Equipment Division, General Electric Company, Erie, Pa., has been appointed manager of the Transportation Division of the company's St. Louis, Mo., office. Mr. Hause has been with General Electric since 1937.

F. C. Brogan (M '47), Electrical Engineer, Ohio Public Service Company, Elyria, Ohio, has joined Commonwealth Services, Inc., Jackson, Mich. He has been with the Ohio Public Service Company since 1924, most recently as supervisor of design in the Central Engineering Department at Elyria.

H. E. Stocking (A '42), engineer, Automatic Washer Section, General Electric Company, Bridgeport, Conn., has been named section manager of engineering. Mr. Stocking joined General Electric in 1940.

V. M. Marquis (A '23, M '31), American Gas and Electric Service Corporation, New York, N. Y., has been elected a Vice-President of the company.

C. W. Schweers (A '37, M '47), Manager, Allis-Chalmers Manufacturing Company, Los Angeles, Calif., has been named Manager of the company's New England region with headquarters in Boston, Mass.

OBITUARY

Robert E. Doherty (A '16, F '39), President Emeritus of Carnegie Institute of Technology, Pittsburgh, Pa., died October 19, 1950. Dr. Doherty was born in Clay City, Ill., on January 22, 1885, and received a Bachelor of Science degree from the University of Illinois in 1909. In 1921 he received a Master of Science degree from Union College and in successive years he received the following honorary degrees: Master of Arts, Yale University, 1931; Doctor of Laws, University of Pittsburgh, 1936; and Doctor of Science, Waynesburg College, 1948. From 1909 to 1931, Dr. Doherty worked for the General Electric Company, Schenectady, N. Y., where he served for six years as assistant to Dr. Steinmetz. At General Electric he was consulting engineer and also headed the company's educational program. In 1931, Dr. Doherty left General Electric to join the faculty of Yale University, New Haven, Conn., as Professor and Chairman of the Department of Engineering. Two years later he was made Dean of the Yale School of Engineering. In 1936, Dr. Doherty became President of Carnegie Institute of Technology where he established a new method of engineering instruction in which emphasis was laid on development of individual competence. After mastery of basic facts, the course was designed to guide the student to the solution of problems by his own ingenuity. Dr. Doherty retired as President of the Institute in July, 1950. The AIEE Lamme Medal was awarded Dr. Doherty in 1937 for his work on electric machinery, and in 1946 he was presented with the Lamme Medal of the American Society for Engineering Education. Dr. Doherty had many papers published in scientific journals and had taken an active part in professional societies. He was a past chairman of the Engineers Council for Professional Development, and a past president of the Society for the Promotion of Engineering Education (now the American Society for Engineering Education). Dr. Doherty had actively served the Institute as a member of the following committees:

Education (1918–19, 1926–28, 1931–35, 1939–41, Chairman 1931–33); Electrophysics (1924–26); Power Transmission and Distribution (1928–29); Technical Program (1931–33); and Edison Medal (1941–46, Chairman 1946). He was also a member of Sigma Xi, Tau Beta Pi, Eta Kappa Nu, and a fellow of The American Society of Mechanical Engineers.

Earle S. Henningsen (A '20, M '26, F '39), Manager of Engineering, Motor and Generator Engineering Department, General Electric Company, Schenectady, N. Y., died September 23, 1950. Mr. Henningsen was born on September 4, 1890, in Oconto, Wis., and received the degree of Bachelor of Science in Electrical Engineering in 1912 from the University of Wisconsin. He joined the General Electric Company in 1912 and had been continuously associated with the company until his death. He was to have retired officially October 1, after 38 years' service. Mr. Henningsen began his career in the Testing Department of which he later became the head. After a short interruption during World War I, when he served the United States Navy as an electrical officer, Mr. Henningsen returned to General Electric, and in 1930 was made engineer in charge of the A-C Engineering Department. Three years later when the D-C and A-C Engineering Departments were combined to form the Motor and Generator Engineering Department, he was appointed engineer in charge of the new group, the position he held until his death. Mr. Henningsen was instrumental in the design of the first synchronous motor for ship propulsion. He also designed the first commercial machine to be cooled by hydrogen and developed the laminated segmental floating rim for large waterwheel-driven generators. This general method of rotor construction completely replaced castings for this type of generator and is in general use in industry today. Mr. Henningsen served the Institute as Section Chairman from 1930 to 1931. He was also a member of the Society of Professional Engineers.

Otis W. Pike (A '30, M '36), Manager of Engineering, Tube Divisions of the Electronics Department, General Electric Company, Schenectady, N. Y., died on October 7, 1950. Mr. Pike was born in Antrim, N. H., on March 10, 1899, and received the degree of Bachelor of Science in Electrical Engineering from the University of New Hampshire in 1920. Mr. Pike had been continuously associated with General Electric since 1920, and had completed successful work in the development and engineering of vacuum tubes. When the Vacuum Tube Engineering Department was formed in 1930, he became designing engineer for the new department; in 1942 he was appointed engineer and held this position when the department became the Tube Division of the newly created Electronics Department. After this unit expanded into the Tube Divisions in 1948, Mr. Pike was made manager of engineering. He held several patents in the vacuum tube field. Mr. Pike had served the Institute as a member of the Electronics Committee from 1947 to the present. He was also a fellow of the Institute of Radio Engineers.

John M. Polonsky (A '49), Senior Engineer, Electrical Engineering Department, Pennsylvania Power and Light Company, Allentown, Pa., died on August 13, 1950. Mr. Polonsky was born on September 5, 1913, in Coaldale, Pa., and was graduated from Pennsylvania State College in 1935 with the degree of Bachelor of Science in Electrical Engineering. Mr. Polonsky had been employed by the Pennsylvania Power and Light Company since 1938, except for three years with the Navy during World War II, when he served as a lieutenant in the Reserve. He was currently a member of the local section's Publicity Committee.

William Charles Winterroth (A '36), District Sales Manager for Rochester, N. Y., The Louis Allis Company, Milwaukee, Wis., died on June 17, 1950. Mr. Winterroth was born on April 20, 1890, in Rochester, N. Y. He joined The Louis Allis Company in 1917, and became District Sales Manager in charge of the Buffalo and Rochester offices two years later. He served the company in that capacity for 30 years.

MEMBERSHIP • • •

Recommended for Transfer

The board of examiners at its meeting of October 19, 1950, recommended the following members for transfer to the grade of membership indicated. Any objections to these transfers should be filed at once with the Secretary of the Institute. A statement of valid reasons for such objections must be furnished and will be treated as confidential.

To Grade of Fellow

Blye, P. W., trans. systems engr., Bell Telephone Labs., Inc., New York, N. Y.

Brown, H. H., chief elec. engr., Wisconsin Michigan Power Co., Appleton, Wis.

Calderwood, E. M., outside plant engr., The Pacific Tel. & Tel. Co., San Francisco, Calif.

Hamilton, J. H., prof. & director, Utah engg. experiment sta., University of Utah, Salt Lake City, Utah

Kinsly, N. T., supt. of distribution & engg., Nashville Electric Service, Nashville, Tenn.

Koenig, H. G., mgr., elec. lab. services, Electrical Testing Labs., Inc., New York, N. Y.

Liwschitz-Garik, M., prof. of elec. engg., Polytechnic Institute of Brooklyn, N. Y.

Mapes, G. M., trans. engr., American Tel. & Tel. Co., New York, N. Y.

Morgan, W. A., elec. engr., Bureau of Reclamation, Denver, Colo.

Nyquist, H., engr., Bell Telephone Labs., Inc., New York, N. Y.

Thomas, E. J., mgr. of engg., specialty transformer & ballast engg. div., General Electric Co., Ft. Wayne, Ind.

Tilles, A., elec. engr., Pacific Gas & Electric Co., San Francisco, Calif.

Whipple, C. C., prof. of elec. engg., Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

13 to grade of Fellow

To Grade of Member

Ball, D. J., plant elec. engr., Newport News Shipbuilding & Drydock Co., Newport News, Va.

Benson, C. R., asst. mgr., sales dist. trans. div., General Electric Co., Oakland, Calif.

Braun, H. J., section mgr., Westinghouse Electric Corp., Lima, Ohio

Brittain, J. B., elec. engr., Westinghouse Electric Corp., East Pittsburgh, Pa.

Campbell, H. C., asst. engr. of motive power, Pennsylvania Railroad, Philadelphia, Pa.

Carothers, B. M., elec. engr., Union Electric Co. of Missouri, St. Louis, Mo.

Climenson, M. G., elec. engr., Bonneville Power Administration, Portland, Ore.

Crockford, J. R., section mgr., Westinghouse Electric Corp., Lima, Ohio

deBritto Pereira, M. P., mgr., vacuum tube div., Standard Electrica, S. A., Rio de Janeiro, Brazil, S. A.

Dike, S. H., research physicist, radiation lab., The Johns Hopkins University, Baltimore, Md.

Dornhoefer, W. J., section head, engg. dept., Vickers Electric Div., St. Louis, Mo.

Gerlach, A. A., engr., armour research foundation, Illinois Institute of Technology, Chicago, Ill.

Ghose, S. C., resident engr. & mgr., Dacca Electric Supply Co., Ltd., Dacca, East Pakistan

Gluckman, H. P., elec. engr., dept. water & power, City of Los Angeles, Calif.

Hampton, P. E., chief engr., Nebraska Public Power System, Columbus, Nebr.

Krug, J. P., senior engr., relay performance, The Detroit Edison Co., Detroit, Mich.

LeBel, C. J., vice pres., Audio Devices, Inc., New York, N. Y.

Lister, E. C., elec. engr., Stanley Engineering Co., Muscatine, Iowa

Loew, H. R., in chge., central station div., General Electric Co., Seattle, Wash.

Malloy, C. T., genl. supt., Southern California Edison Co., Los Angeles, Calif.

Markese, J., design engr., Delta Star Electric Co., Chicago, Ill.

Monson, C. F., Jr., asst. supt., Puget Sound Power & Light Co., Seattle, Wash.

Mueller, W. J., jr. physicist, ames lab., Iowa State College, Ames, Iowa

Nader, J., pres. & chief engr., Nader Engineering Co., Chicago, Ill.

Noland, J. W., supt. of instruction, Electronic Radio Television Institute, Omaha, Nebr.

Press, M., project elec. engr., eclipse-pioneer div., Bendix Aviation Corp., Teterboro, N. J.

Schmand, D. A., engr., dept. of army, Corps of Engineers, Little Rock, Ark.

Scott, N., elec. engr., Hughes Aircraft, Culver City, Calif.

Skinner, J. H., engr., Busch Brothers, Inc., Englewood, N. J.

Smith, H. T., instructor, speed school, University of Louisville, Louisville, Ky.

Taliman, W. C., technical asst., Public Service Co. of New Hampshire, Manchester, N. H.

White, J. A., chief of service div., ames aeronautical lab., National Advisory Committee for Aeronautics, Moffett Field, Calif.

Wolfson, W., electronics engr., navy materiel lab., New York Naval Shipyard, Brooklyn, N. Y.

33 to grade of Member

Applications for Election

Applications for admission or re-election to Institute membership, in the grades of Fellow and Member, have been received from the following candidates, and any member objecting to election should so notify the Secretary before December 25, 1950, or February 25, 1951, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Member

Aaroe, E., Gibbs & Hill, Inc., New York, N. Y.

Adams, C. J., Kellogg Switchboard & Supply Co., Chicago, Ill.

Bausch, K. M., Bechtel Corp., San Francisco, Calif.

Beaumont, F. N., Anglo-Iranian Oil Co., London, England

Calder, D. G., Riverside Utility Co. Ltd., Ultenhage, Cape Province, South Africa

Dearing, L. M., Technicolor Motion Picture Corp., Hollywood, Calif.

de Kalman, O., General Foods Corp., Battle Creek, Mich.

DeWinter, J. A., J. & G. Daverman Co., Grand Rapids, Mich.

Forman, A. H., Jr., Central Arizona Light & Power Co., Phoenix, Ariz.

Hanson, W. F., Walter Gordon, Jr., Consultant, Tacoma, Wash.

Harper, P. F., Potomac Elec. Power Co., Washington, D. C.

Hinton, D. R., Jr., Gulf Power Co., Pensacola, Fla.

Hollowell, W. P., U. S. Naval Air Station, Pensacola, Fla.

Johnson, H. W., The Ideal Elec. & Mfg. Co., Mansfield, Ohio

Jones, S. F. G., New York Telephone Co., New York, N. Y.

Khanna, M. L., Punjab Public Works Dept., Punjab, India

Kirby, T. R., The Zia Co., Los Alamos, New Mex.

Lind, R. F., National Spectrographic Laboratories, Cleveland, Ohio

Lloyd, S. M., Western Elec. Co., Inc., New York, N. Y.

MacLean, N. W., American Tel. & Tel. Co., New York, N. Y.

Mathis, L. B., C. H. Guernsey & Co., Oklahoma City, Okla.

McGregor, D. R., Canadian General Elec. Co. Ltd., Peterborough, Ontario, Canada

Metzner, M. W., (re-election), General Elec. Co., Erie, Pa.

Miller, F. A., Mines Engineering Co., Chicago, Ill.

Morrical, K. C., Washington Univ., St. Louis, Mo.

Murphy, J. L., Armour Research Foundation, Chicago, Ill.

Ramey, R. A., Naval Research Lab., Washington, D. C.

Rowe, O. R., R. H. Bouligny, Inc., Charlotte, N. C.

Smith, W. R., Pennsylvania Power & Light Co., Allentown, Pa.

Stehman, H. E., General Elec. X-Ray Corp., Milwaukee, Wis.

Stenhammar, H. T., Ericson Tel. Sales Corp., New York, N. Y.

Tognola, T., Bendix Aviation Corp., Sidney, N. Y.

Whitney, A., Westinghouse Elec. Corp., Baltimore, Md.

33 to grade of Member

OF CURRENT INTEREST

Doctors See Operating Table Techniques by Color Television

Industrial color television now enables doctors and medical students to view surgical operations in parts of the hospital where there is adequate room, comfort, and the opportunity to discuss what is taking place as the operation proceeds. Such a demonstration of Du Mont industrial color television has taken place at St. Clare's Hospital in New York, for the benefit of doctors attending the Twenty-third Graduate Fortnight of the New York Academy of Medicine. Several hundred doctors have televiewed one or more of the latest surgical techniques, thereby learning by seeing what might not otherwise be seen because of the limitations of the amphitheatre system.

The color camera was set up in a corner of the operating room on the fifth floor of the hospital, as shown on the cover picture. The color control equipment was located in an adjoining room. From the control equipment a coaxial cable led to the demonstration rooms on the first floor, where the remote audience could witness the intimate details of the operation by means of a battery of color television receivers. Not only the rendition in natural color but also the degree of pictorial resolution or photographic detail considerably greater than that possible in home television give the kind of realism essential to following and appraising surgical technique.

This type of industrial color television is designed strictly for closed-circuit operation; camera and receiver are directly connected by private cable. Consequently, such television is not subject to the frequency bandwidth restrictions and other limitations imposed on broadcast television. Freed from such restrictions, engineers have been able to develop higher standards of fidelity, keeping in mind only the compromise between cost and practicability. No Federal Communications Commission license is required to operate this industrial television system.

Even though the camera was placed some distance from the operating table so as not to interfere with the operating personnel and patient, its lens turret permitted long shots, medium shots, and intimate closeups at will. The camera was equipped with a trigger lock multilens selector handle and a pan-handle focusing means, for instant change of lenses. Color-control monitor units were some distance away at a single control point in another room. The entire operation of the camera chain is performed by a single operator unless continuous movement of the camera is desired. The five compact, lightweight units, including the camera, are highly portable. Special connectors and cables permit ready setting up or disassembling of equipment in going from one location to another.

This development will enable students in medical schools to see at first hand the new surgical techniques being practised. The medium of television provides an immediacy which can only be achieved otherwise by the viewer actually being present in the operating room. Further, detailed related instructions may be included for a particular group of viewers in accordance with their special instruction requirements during routine periods of an operation. Teaching techniques may be varied to best suit the viewer groups at each presentation.

The operation is under way as the color camera picks up the scene at St. Clare's Hospital

New Tube System Solves Problems of Interoffice Communication

A pneumatic tube system incorporating the selective "mechanical brain" principles of the dial telephone and rivalling in speed and efficiency the operation of the most modern dial telephone exchange has been introduced recently by the International Standard Trading Corporation, an associate of the International Telephone and Telegraph Corporation (I.T.&T.). A product of Mix and Genest, a German subsidiary of I.T.&T., the new system is the first completely automatic approach to the problem of interoffice communication yet developed.

A notable feature of the equipment is a special selective dial in the carrier which permits the sender to forward his message or article to any other of a number of stations without the intervention of an operator or central dispatcher. Although it was designed primarily for department stores and industrial plants, the new automatic equipment is especially well adapted for use in hospitals, where records, prescriptions, medicine, and so forth, often must be dispatched with as little handling as possible.

Unlike the conventional tube installations which require separate sending and receiving lines for intercommunication between two or more stations, the Mix and Genest system is designed to provide full automatic service between all stations. The defects common to manually operated systems are ingeniously eliminated by providing common, automatically controlled loop lines. Each of these loop lines begins at a central point and is connected to a number of stations. All carriers flow through their sending loops to this central automatic control point where they are automatically directed to their destinations by a relay panel—just as a telephone call might be routed under the dial switching system. Leaving the central station through the appropriate receiving loop lines, the carriers are admitted selectively at their destined stations by automatic switches.

Future Meetings of Other Societies

American Management Association. General Management. January 15–18, 1951, Biltmore Hotel, Los Angeles, Calif.

The American Society of Mechanical Engineers. 19th National Exposition of Power and Mechanical Engineering. November 27–December 2, 1950, Grand Central Palace, New York, N. Y.

American Society of Refrigerating Engineers. 46th Annual Meeting. December 3–6, 1950, New York, N. Y.

Hydraulic Institute. December 3–5, 1950, Seaview Country Club, Absecon, N. J.

National Association of Engineering Companies. General Meeting to discuss the 1950 Defense Production Act. December 12, 1950, Detroit, Mich.

Pennsylvania Electric Association. Winter Meeting of Transmission and Distribution Committee. February 1–2, 1951, William Penn Hotel, Pittsburgh, Pa.

Society of Plastics Engineers, Inc. Seventh Annual National Technical Conference. January 18–20, 1951, Hotel Statler, New York, N. Y.

The Mix and Genest pneumatic tube system utilizes many of the principles embodied in automatic telephone switching, yet is considerably less complicated. The dial carrier serves much the same function as the telephone dial. On each of the carriers are rings stamped with digits, from zero to nine. These rings are adjusted to the number corresponding to the receiving station, and the carrier is inserted in the transmitter of the dispatching or sending station. It then travels by suction to the automatic central control point. Here, the carrier stops briefly, while contact fingers touch the contact rings of the carrier. As the relay panel or "brain" of the system reads the signal dialed on the carrier, it actuates the appropriate line and station switches and immediately diverts the carrier to the correct outgoing line and station. After having passed the central station, the carrier travels through the receiving line determined by the signal of the dial rings to the destination point, where the station switch has already been operated by the relay panel. There it is finally delivered through the receiver flap.

The relay panel is an important part of the equipment. It not only determines the course of the carriers, but counts for traffic study purposes how many of them pass through each loop, provides the appropriate space interval between traveling carriers, and flashes alarm signals to a supervisor should any failure occur in any part of the system. In addition, the relay panel controls a signal panel on which the lines in operation, the blower performance, blown fuses, or incorrectly dialed carriers are visually indicated.

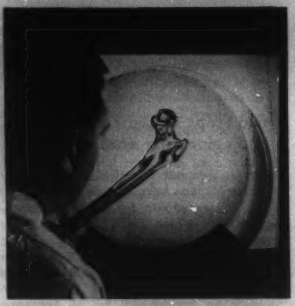
Errors are virtually impossible, even if a carrier is dialed for transmission to a nonexistent station. Should this occur, the central control device will dispatch the carrier to any desired supervisory position—the telephone operator's desk or any other convenient location.

The number of stations which may be employed is practically without limit and may vary from a few automatic stations with push buttons instead of a central to several automatically operating pneumatic tube centrals, with interconnecting facilities for hundreds of sending and receiving stations. A 40-station system can handle as many as 1,200 carriers an hour.

New Plastic Provides "Internal Vision" for Engineers

A new plastic that can be made into scale models of machine parts and tools now is providing "internal vision" for engineers in military, university, and industrial laboratories, according to the Westinghouse scientists who developed it. The new "photoplastic" is aiding researchers in gun factories, airplane engine plants, arsenals, naval laboratories, and universities in the design of stronger machinery and equipment. The 3-dimensional scale models cut from the plastic enable scientists to get a "portrait in color" of the strains encountered in tools, machine parts, and other objects.

One of the major applications of the new material is in the design of breech blocks for big guns. To understand the terrific stresses these parts undergo during firing of the gun, an exact 3-dimensional model of



The color pattern which is "frozen" into this plastic model of a human leg bone reveals where fracture might occur if bone were subjected to jarring impact. Concentration of stress lines in the socket where the bone joins the hip shows this to be a danger zone

the block has been built and "loaded" to simulate the stress. When frozen into the material and then viewed through special polarized light, the stress pattern appears as a series of varicolored lines that tell the scientist where the major stresses are located, in which direction they are acting, and just how great they are.

Even medical scientists may find the new material of great value because experimental leg-bone models have shown that internal stresses in human bone structure such as those caused by fractures or heavy blows can be clearly viewed and analyzed.

The new plastic is a modified form of Fosterite, a waterproof material developed by the Westinghouse Electric Corporation during World War II to seal radio and radar parts against moisture.

Northwestern to Build 4,500,000-Volt Atom Smashing Accelerator

Northwestern University today announced that it will build a 4,500,000-volt electrostatic accelerator for nuclear research. Construction of the 28-ton atom smashing equipment will begin within two months, but it will be at least two years before the work is completed.

The instrument, a Van de Graaff-type ion accelerator, will be installed in a structure to be built just south of the Northwestern Technological Institute. The lower part of the building probably will be underground so that the earth will serve as a shield for protection against the powerful rays produced by the generator. Additional protection will be provided by concrete walls and ceilings at least two feet thick.

Cost of the project will be approximately $150,000, exclusive of the housing. The apparatus will be designed and constructed under supervision of members of the Physics Department, with co-operation of members of the Northwestern University Technological Institute staff. A greater part of the construction will be done in the Physics Department machine shop.

Northwestern physicists will use the Van de Graaff unit in searching for new information about the behavior of atomic nuclei when bombarded by high-speed particles. This may be expected to yield further knowledge bearing on the nature of the forces which hold atoms together.

Stevens Institute of Technology Acquires Mechanical Brain

Stevens Institute of Technology has acquired an analogue computer, which was loaned to the college by the Office of Naval Research. The acquisition of this experimental model makes Stevens one of the first engineering schools to have such a device.

The big machine with the operating console, occupying an area of more than 100 square feet and rising seven feet from the floor, has been housed on the second floor of the Navy Building on the campus, in a room directly beneath the computer laboratory.

The mechanical brain, which can add, subtract, divide, integrate, differentiate, solve complex problems in trigonometry, and perform all the basic mathematical operation, will be used for research computations by the Experimental Towing Tank and other research activities at Stevens, and for instruction in connection with a graduate course in computing devices.

In the laboratory students study the components of a computer such as adding devices, multipliers, and differentiators, as well as mechanical memories. They design computers and develop certain parts in detail and test them. The new analogue computer will enable students to see the complete device in action and to study its possible applications in many industries.

Army Signal Corps Perfects New Type Noise Meter

Man-made interference or noise heard on radio or television sets when an electric shaver or vacuum cleaner is plugged in may some day be eliminated as a result of research now being conducted at the Signal Corps Engineering Laboratories, Fort Monmouth, N. J.

Army scientists are staging a multi-pronged attack on this noise by developing suppression methods capable of muzzling the interference. Unsuppressed noise cuts down both the range and quality of the Army's various communications systems.

Latest advance in this 10-year-old war is the perfection of a new type "noise meter" which can accurately measure the unintentional interference or radiations produced by electric fans, oil burners, automobile ignition systems, refrigerators, and dozens of other household and industrial products. The new meter not only tells the Army whether the items will interfere with its communications, but also gives, for the first time, a true picture of the fundamental properties of noise, such as its peak value and repetition rate.

Earlier models of the meter covered frequencies used primarily for amplitude-modulated radio signals. The new meter

has a greatly extended frequency range and can be used not only for the amplitude-modulated signals but for frequency-modulated radio signals, radar, television, facsimile, and radioteletype, all used by the Army, as well.

Accurate information of noise, as provided by the new meter, is important to the Army because electronic receivers in the front lines are often located in vehicles. Radiations given off by the operating jeeps, trucks, and tanks, unless suppressed, may help give away troop positions through detection by enemy listening posts. To prevent this possibility and to improve communications, the Signal Corps has not only worked with equipment producing noise but also with the design of receivers and with the signals themselves. Many of the findings have already been adapted by industry in building equipment which will not interfere with signal transmission.

National Electronics Conference Has Registration of 2,350

The 1950 National Electronics Conference, held on September 25, 26, and 27 at the Edgewater Beach Hotel in Chicago, Ill., was highly successful with a total registration of 2,350. Many of the technical papers presented were on industrial electronics.

One of the features of the conference was an address by Wayne Coy, Chairman of the Federal Communications Commission. Mr. Coy discussed the recent decisions of the Commission in regard to color television.

Proceedings of the 1950 conference will be published early in 1951. Copies of volume 6 (1950) and of preceding volumes except volume 1 (1944), which is out of print, may be ordered from National Electronics Conference, Inc., 852 East 83rd Street, Chicago 19, Ill. Volume 2 (1946) is $3.50; subsequent volumes, including the forthcoming volume 6 (1950), are $4.00.

Broad Scope of Centennial of Engineering Outlined

Eleven national technical societies and one from Canada have already taken formal action to participate in the international convocation which will celebrate one hundred years of engineering as an organized profession in the United States. This convocation, organized under Centennial of Engineering, 1952, Inc., is designed to "provide an opportunity for all engineers to gather to exchange ideas and information of value to one another with no one group taking a place of special prominence."

At a meeting on October 12, the incorporators of Centennial of Engineering authorized President Lenox R. Lohr to extend invitations to an additional 60 technical societies in this country, and to appropriate societies of international scope or of national scope in other countries. The international societies will be invited to hold their annual meetings in Chicago, Ill., during the Centennial Convocation from September 3 to 13, 1952. Where it is not feasible for the societies of other countries to hold meetings in this country, it is hoped that they will send representatives to the convocation. The Centennial Convocation will give engineers an opportunity to attend meetings and hear technical papers of the other branches of engineering, and to obtain pertinent information on the developments available to them from specialists outside their own fields.

An important part of the Centennial of Engineering celebration will be an Exposition during the months of July, August, and September 1952. The incorporators of the Centennial of Engineering have stated: "The purpose of the Centennial Exposition should be to tell the story of engineering and industry to the general public."

This story will be told in many ways at the Exposition which will be held at the Chicago Museum of Science and Industry. First in public appeal will be a stage production in the 1,000-seat main auditorium of the museum. This show will be a dramatic human interest pageant about America—how it grew and prospered over the years, and how it can continue to grow. The essential role of the engineer and his industrial machine will be woven into the story just as it has been woven into our daily lives.

A permanent engineering exhibit will be built in the museum, where it may be open to visitors the year round for five years or more. This exhibit, occupying over 8,000 square feet of floor space, will utilize dioramas, models, and full-sized equipment to show the evolution of engineering and of the engineer over the last 100 years. This exhibit will contain examples of every field of engineering, and will be planned to show how the products of dozens of different specialists come together to make one complete complex machine.

Wayne Coy, Chairman of the Federal Communications Commission, addressing the members of the National Electronics Conference on color television at the September 25 luncheon at the Edgewater Beach Hotel, Chicago, Ill. At the left is Nathan Cohn, Chicago District Manager, Leeds and Northrup Company, and President of the 1950 National Electronics Conference. At the right is Dr. O. W. Eshbach, Dean of Engineering, Northwestern University

GE Dedicates New Research Laboratory at Schenectady, N. Y.

The observance of the 50th anniversary celebration of the nation's first industrial research laboratory, the General Electric Research Laboratory, was marked by the formal dedication of the laboratory's new home at the Knolls near Schenectady, N. Y. Charles E. Wilson, company president, formally dedicated the new laboratory "to the advancement of scientific knowledge" and presented a golden key marking the golden anniversary to Dr. C. G. Suits, General Electric vice-president and director of research.

The General Electric Research Laboratory was established in 1900 when company officials recognized that they should provide some new source of fundamental scientific knowledge for the technology of the future, particularly as it concerned the electrical industry. The present laboratory, still devoted primarily to fundamental research, now has a staff of over 800 of which about a quarter are scientists.

The event marked the beginning of a program which ran for a week. It included the annual meeting of the National Academy of Sciences, held for the first time in its 88-year history at an industrial laboratory.

ECE Electric Power Committee Concludes Seventh Session

The Committee on Electric Power of the United Nations Economic Commission for Europe (ECE) recently concluded its seventh session at Donzere-Mondragon, France, where it inspected the construction of Europe's largest power project west of the Soviet Union's frontier.

The session opened in Geneva where

delegates from 14 European countries and the United States dealt with three major problems of immediate interest. These were: the promotion of increased imports of electric energy into Bavaria, the development of rural electrification in Yugoslavia, and the settlement of legal problems concerning the development of rivers and lakes of interest to two or more European countries.

The Committee completed a 17-point agenda covering economic, technical, legal, and cartographic questions related to energy production and distribution and the development of electric power resources. As a basis for their discussions the government and industry representatives had before them 16 Secretariat studies.

The session was attended by representatives of Austria, Belgium, Denmark, Finland, France, Italy, Luxembourg, Netherlands, Norway, Poland, Sweden, Switzerland, United Kingdom, United States, Yugoslavia, and the International Labor Office. Mr. Pierre Smits (Belgium) was elected Chairman; Mr. E. H. Etienne (Switzerland), Vice-Chairman. The committee will meet again next February.

Eastman Kodak Scientists Battle Motion Picture Dust

A new method of determining the electrostatic charge on motion picture film may help projectionists, both amateur and professional, in winning the battle against dust.

Dust particles, attracted to film when it becomes charged with static electricity, have long been an enemy of the motion picture projectionist. For one reason, a dust speck is magnified hundreds of times when it appears on the screen. However, new apparatus and techniques developed by Eastman Kodak scientists for determining the charge on film may lead to defeat of the problem.

Basically, the problem is this: motion picture film, or any photographic film, becomes electrified when rubbed or passed over rollers. The electrostatic charges which are generated attract dust to the film.

The new device developed by Kodak is designed to measure accurately the electrostatic charge on photographic film. Using the apparatus, researchers can study properties of various materials used in film rollers to learn how much the film is electrified.

Important to the projectionist, however, are results of studies of picture film cleaning materials. The new charge-measuring device has been used in studies which show that film receives varying charges from different materials.

Dry velvet, for example, does not appreciably change the charge of processed Eastman Plus-X Negative Film when rubbed on either the emulsion or support side. Velvet wetted with carbon tetrachloride will hold the film at a constant charge when rubbed on the emulsion side. But when it is rubbed on the support side, the film is almost completely discharged, and thus less likely to attract dust particles.

Award Winners Announced in Product Design Competition

Five awards for outstanding achievement in the development of new electrically operated products are announced by The Gage Publishing Company, N. Y., as the result of the Twelfth Annual Electrical Manufacturing Product Design Awards Competition sponsored by the publishers.

The awards have been made to Altec Lansing Corporation, Hollywood, Calif., for a miniature microphone; to Ampex Electric Corporation, San Carlos, Calif., for a professional magnetic tape recorder; to Landers, Frary & Clark, New Britain, Conn., for a sectional-type electric range; to Radio Corporation of America, Victor Division, Camden, N. J., for a permanent magnet electron microscope; and to The Springfield Machine Tool Company, Springfield, Ohio, for an engine lathe.

New Westinghouse Educational Center Recently Opened

The new Westinghouse Educational Center, a nonprofit corporation organized to offer to employees of Westinghouse and their families opportunities for further educational and cultural development, was recently opened.

The new structure is located on a 10-acre plot in Wilkensburg, Pa., a borough adjoining metropolitan Pittsburgh. A large portion of its floor space houses six ultramodern classrooms and a large lecture hall where the Westinghouse evening graduate study program is carried out in co-operation with the University of Pittsburgh.

Courses in virtually every phase of engineering are taught by a faculty made up of Westinghouse scientists and engineers and University of Pittsburgh professors. Other classes are held on the campus of the University of Pittsburgh under special arrangements of a co-operative study plan.

Almost all of the courses are offered in the evening so that employee students can continue their full-time occupations. This year some 350 students are expected to participate in the program.

General Electric Education Fund Applications Now Being Accepted

Applications for research grants are now being accepted under the $1,000,000 General Electric Education Fund for the scholastic year 1951–52. Under the program, now in its 27th consecutive year, aid in grants up to $1,500 annually will be awarded to college graduates who wish to continue individual study in scientific and industrial fields.

Applications for the fellowships which must be filed by January 1, 1951, have been distributed to libraries of engineering schools, department heads of electrical and mechanical engineering schools, professors of electrical and mechanical engineering, physics, chemistry, and metallurgy, and deans of graduate schools. Applications must be mailed to the Secretary, General Electric Company Education Fund, Schenectady, N. Y.

Individual fellowships up to $1,500 annually may be granted, with a grant of $500 available for specific apparatus or other expense in connection with the research. The grant for apparatus may be requested after the awarding of the fellowship.

Fellowships are intended for graduates who need financial assistance and who have shown by the character of their work that they could with advantage undertake or continue research in this country or abroad. They are not intended for graduates who now hold, or expect to hold, any other fellowship which carries a stipend larger than the tuition of the institution where the research work is to be done.

A committee representing the AIEE, National Academy of Sciences, American Chemical Society, American Physical Society, The American Society of Mechanical Engineers, and American Society of Engineering Education will pass upon all candidates for the fellowships.

GE Announces Redesigned Line of Thermocouple Vacuum Gauges

A redesigned line of thermocouple vacuum gauges for industrial, laboratory, and other applications where vacuum must be accurately measured has been announced by General Electric's Meter and Instrument Divisions.

Included in the line are a 115-volt a-c portable thermocouple vacuum gauge, as well as types for both rack and panel mounting. All but the rack-mounted type have been designed to operate either from 115 volts a-c or from number 2 flashlight batteries.

Usable on either glass or metal vacuum systems, the gauges give a continuous indication of pressure and respond almost instantly to pressure changes. Pressure can be read directly from a scale calibrated from 0–200 microns. In the 1–100 micron range, the instruments are accurate within 10 per cent of the reading or one micron, whichever is greater.

The gauge is connected to the gauge tube electrically; hence it may be disconnected from the tube without disturbing the vacuum system. The gauge tube may be interchanged without the need for calibrating the indicating instruments. The vacuum-gauge tube is built to withstand damage if accidentally operated at atmospheric pressure.

Estes, Colorado, Plant Ready For 3-State Power Needs

The first 15,000-kw generating unit of the Estes power plant on the Colorado-Big Thompson project of the Bureau of Reclamation was put in service recently to meet expanding electrical requirements in Colorado, Wyoming, and Nebraska. This unit, which has been furnishing voltage regulation for the Bureau's interconnected power system since September 17, will provide critically needed reserve capacity during possible emergency conditions. A second unit of 15,000-kw capacity is scheduled for operation on the same basis by November 1, and a third and final unit of 15,000 kw will be completed in December.

Full continuous power production from Estes Power Plant will be achieved when Granby Reservoir is substantially full, some two years from now. The beginning of the storage of water that will increase in value five times within the next three years is now

under way at Granby Reservoir. When the Colorado-Big Thompson project is completed, the water now being stored in Granby Reservoir will be run through the completed power system instead of the two now essentially completed. The objective of the Bureau of Reclamation now is to get Granby Reservoir filled so that when operations begin throughout the entire system in 1953 the full project can be operated in the most economical manner.

Detroit Edison Builds Generating Plant in St. Clair, Mich.

Detailed plans for a new 400,000-horsepower electric generating plant to be built on the St. Clair River front, midway between Marine City, Mich., and St. Clair, Mich., were announced recently by The Detroit Edison Company. This addition to Michigan's industrial and domestic power supply will be known as the St. Clair Plant.

Recent world events led to a decision to build a new plant instead of installing extra generating equipment in an existing plant, as originally planned. The revised plan would enable the company to keep in service three older generators which were marked for retirement before the outbreak in Korea. Also, the separate location of the plant would further decentralize Edison generating facilities. (The four existing Edison power plants are strung out along a 65-mile sector from Trenton to Port Huron.)

The new plant will be equipped with two steam turbogenerators with "nameplate ratings" of 125,000 kw each. Actual capability of the plant will be in excess of 300,000 kw, or 400,000 horsepower.

Completion of the project, scheduled for the end of 1953, will bring the Edison Company's total capacity to more than 2,600,000 horsepower. The two new turbogenerators already have been ordered. The machines are designed for high fuel economy. The boilers will be fired with pulverized coal, and stacks will be equipped with electrostatic dust collectors to assure clean operation.

Annual Report of United Engineering Trustees, Inc. The report by Edward C. Meagher, President, covers the corporation's operation and financial handling of the Engineering Societies Building and its financial program; the operation of the Engineering Societies Library; and the financial operation incident to the care of funds for conducting the chartered purposes of the corporation. Because of the growth of the societies, the present quarters at 33 West 39 Street have proved inadequate and a larger building is being sought—one which could become an engineering center uniting the various engineering societies under one roof. Any AIEE member can obtain a copy of the complete report by requesting it from Mr. John H. R. Arms, Secretary, United Engineering Trustees, Inc., 33 West 39 Street, New York 18, N. Y.

Boston Orders 90 Trolley Coaches. An order for 90 trolley coaches for Boston costing approximately $18,000 each has been placed with the Pullman Standard Car Manufacturing Company of Worcester, Mass. These 44-passenger silent electric trackless trolley coaches will be delivered in the spring of 1951 for feeder service to an extended rapid transit system serving East Boston, Revere, and Chelsea. When placed in service, Boston will have a total of 430 trolley coaches in service, making it the third largest operator of this type of vehicle in the United States. Chicago is first with 710 and Atlanta is second with 453 trolley coaches.

RTMA Engineering Department Moves. The New York headquarters of the Radio-Television Manufacturers Association's Engineering Department and Data Bureau was moved in November from 90 West Street to 489 Fifth Avenue. The RTMA office is located in suite 710–711 and the new telephone numbers are Murray Hill 2-8190—8191—8192. Larger space will take care of the continuing expansion of services given by the RTMA Engineering Department.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Electromagnetic Induction

To the Editor:

In the November 1949 issue of *Electrical Engineering*,[1] I had very briefly calculated the electromotive force generated by a Faraday disk rotating in an alternating magnetic field. This brevity was unfortunate, since it allowed the problem to be badly misconstrued, as illustrated by L. V. Bewley's letter to the editor in the December issue.[2]

The original problem was to calculate the electromotive force generated by the Faraday disk shown in Figure 1. It is important to note that the meter circuit (external to the disk) is entirely contained in the yz plane, to which there is no perpendicular component of magnetic field (since $\mathbf{B} = 1_x B_0 \cos \omega t$). Bewley has changed the subject by making a literal "substitution of circuit" from that shown in Figure 1 to that shown in Figure 2. This introduces an electromotive force generated by transformer induction which is not present in the original circuit and is due to the rearrangement in the geometry of the external circuit. To avoid this extraneous contribution of electromotive force, it is necessary to restrict the external circuit to that shown in Figure 1.

A superficial view of the problem may make it appear unduly complicated because the magnetic field produced by the eddy currents must be included in the total magnetic field. Since it is desired to perform an experiment to illustrate the principle, the experiment may be so arranged that the induced eddy currents are small, and the magnetic field they produce will be negligible compared to the magnetic field of the external source. This may be accomplished simply by having (a) the resistance of the disk large, (b) the frequency of the alternating magnetic field low, or (c) both. A thin metal foil supported on a wooden disk in a 60-cycle magnetic field will have, for the purpose of this experiment, negligible induced eddy currents. Moreover, even if the field created by the eddy currents is not negligible, it is merely necessary to use the total magnetic field in the calculation.

Bewley's method of replacing a solid disk by spokes would appear to be inadmissible because it changes the physical nature of the problem. He states that if it be objected that a single spoke is hardly a disk, we have only to observe that the same analysis holds for several spokes, and a solid disk may be looked on as an infinite number of spokes infinitely close together. First of all, the external circuit for the multiple spoke case is not the same as that for the single spoke case, thereby invalidating comparison. Furthermore, the solid disk has a finite resistivity in the angular direction whereas the spoked wheel has an infinite resistivity in this direction. In the solid disk, the magnetic field and, hence, the induced eddy currents are independent of the angular co-ordinate. Therefore, the transformer-induced electromotive force which causes the eddy currents is exactly cancelled out over every portion of every path by the eddy current drop,

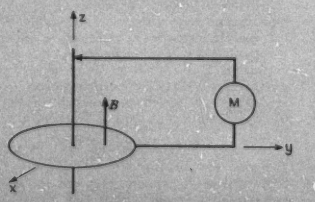


Figure 1. Generation of electromotive force by Faraday disk

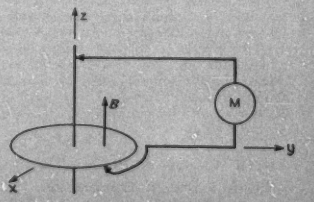


Figure 2. Synthetic Faraday disk generation

and hence this transformer-induced electromotive force does not appear in the output of the Faraday disk. In the spoked case, the eddy currents are not allowed to flow because of the infinite resistivity in the angular direction, hence there is no eddy current drop and the transformer electromotive force produced appears in the output, thereby completely changing the nature of the problem.

Bewley's technique of using the flux linking law, $\mathcal{E} = -d\phi/dt$, plus substitution of circuit is not a general method because there is no general formulation for the required substitution of circuit. In each different case where the substitution of circuit method would be applied, it is necessary to devise a different substitution of circuit. The student of this method would not be able to solve a problem which required a substitution of circuit different from those he has previously experienced because he has no general method for their construction, unless, of course, the answer is known to begin with and the substitution is tailored to give the known result. To illustrate this, consider the Faraday disk in a magnetic field which is a function of the angular coordinate. Using Bewley's substitution of any finite number of spokes for the solid disk, the electromotive force generated would vary with the angular position of the spoke disk; however, the electromotive force generated will not depend on the angular position of the disk. This illustrates that the substitution of circuit method employed by Bewley lacks general validity. It is interesting to point out that in this case even the motionally induced electromotive force will cause eddy currents to flow.

It is Bewley's viewpoint (see paragraph 1 of reference 2) that the flux linking law never breaks down. The Faraday disk is an example of such failure. If $\mathcal{E} = -d\phi/dt$ did not break down, it would not be necessary to introduce the substitution of circuit idea. Bewley incorrectly states that I deny the substitution of circuit idea and that in my article "Electromagnetic Induction"[3] I rejected the idea entirely. My article demonstrates why the flux linking fails in some cases, thereby actually substantiating the fact that some artifice such as the substitution of circuit idea must be used in addition to $\mathcal{E} = -d\phi/dt$ in these cases in order to obtain the correct result.

The flux linking law, $\mathcal{E} = -d\phi/dt$, is an extremely useful law; however, in those cases in which it must be manipulated in a generally unpredictable manner to fit particular cases, it is advisable to calculate the total electromotive force from the fundamental formulae for transformer and motional induction. The criteria[3] for the foolproof use of the flux linking law without impedimenta, is, paraphrased, *the motion of every segment of the circuit* (in which the induced voltage is being calculated) *must be the same as the motion of the material instantaneously comprising the segment.*

In the accompanying letter Mr. Bewley makes it clear that in the case of the brush being in the plane of the external circuit and axis of the Faraday disk, only the motional terms of the induced voltage, which he himself refers to as "flux cutting action," survive, and that an experiment will show this voltage. This is the case I discussed in my letter to the editor;[1] to what extent the just-mentioned statements of Professor Bewley represent a reversal of the statement which he made at the beginning of his letter,[2] I leave to the judgment of the reader.

Bewley remarks, "Substitution of circuit is a real and physical process, easily identifiable in every case I have ever come across . . . ." In all of Bewley's examples he uses wires, that is, 1-dimensional elements. Circuital concepts apply nicely when only 1-dimensional elements are involved, but lose a large part of their significance when applied to a 2- or 3-dimensional body. Hence, without substituting a spoked wheel (a structure of 1-dimensional elements) for a solid disk (a 2-dimensional element) I doubt that it can be shown that a real physical process constituting a substitution of circuit is occuring. Bewley's elaborate "universal generator" (see his accompanying letter. Ed.) still does not make the solid disk a special case of a spoked wheel.

Bewley has erroneously remarked that I have confused $d(n\phi')/dt$ with $n\,d\phi'/dt$ and was forced to the unwarranted conclusion that $n\,d\phi'/dt$ does not always give the induced voltage. In my presentation, I have never made any mention of number of turns n even though the concept of turns may be very useful and save labor in many calculations. The definition of flux ϕ which I use is that given by Stratton, Smythe, Abraham and Becker, and others, and is $\phi = \int\int \mathbf{B} \cdot d\mathbf{S}$ where the surface over which $\mathbf{B}$ is integrated is that whose periphery is the circuit which the flux ϕ interlinks. In those special circumstances where the contour almost overlaps itself a number of times n so that each overlapping can be considered to constitute a closed curve, and if the flux through each of these closed curves is the same value, say ϕ', then $\phi = n\,\phi'$. In such special circumstances the concept of "number of turns" finds its greatest usefulness. In other cases where the turns do not form such closed curves, only equivalent turns may be spoken of and these do not have such usefulness.

REFERENCES

1. Letter to the Editor, **George I. Cohn.** *Electrical Engineering*, volume 68, November 1949, pages 1018–19.

2. Letter to the Editor, **L. V. Bewley.** *Electrical Engineering*, volume 68, December 1949, pages 1113–14.

3. Electromagnetic Induction, **George I. Cohn.** *Electrical Engineering*, volume 68, May 1949, pages 441–47.

GEORGE I. COHN (M '50)

(Assistant Professor of Electrical Engineering, Illinois Institute of Technology, Chicago, Ill.)

To the Editor:

Mr. Cohn agrees that the Faraday disk in a pulsating magnetic field has induced in it both a transformer and a motional electromotive force; even though (as first pointed out in my letter to the editor, *EE, Dec '49, pp 1113–14*) the transformer electromotive force is consumed by eddy currents within the disk itself, so that only the motional component appears in the external circuit. My sole purpose in suggesting that the disk be replaced by a spoked wheel, with the rim interrupted between every pair of spokes, was to provide a simple way of calculating, and verifying by test, the existence of the transformer component of electromotive force. And my only reason for putting the brush out of the plane of the external circuit was to exhibit a more general problem, which (as I showed) contains Cohn's example as a special case ($\theta = 0$).

Cohn remarks that I believe the flux linking law, $d(n\phi)/dt$, never breaks down (as a measure of induced voltage). May I insist that such is not my view. In my 1929 paper[1] and in a subsequent discussion,[2] I did my best to show analytically, and by numerous examples, that the induced voltage does not necessarily bear any relationship to the rate of change of flux linkages. It is quite possible to have zero voltage associated with a finite rate of change of flux linkages, or a finite voltage associated with zero rate of change of flux linkages, or a specified voltage associated with any arbitrary rate of change of flux linkages; depending entirely on the relationship between $n\,d\phi/dt$ (which induces a voltage) and $\phi\,dn/dt$ (which does not induce a voltage).

On the other hand, I do maintain that the induced voltage is always and unequivocally proportional to the rate of change of the flux which is linked with the circuit at a given instant. The difference between rate of change of flux linkages and rate of change of flux is accounted for by any substitution of circuit which may take place. A substitution of circuit is a real and physical process, easily identifiable in every case I have ever come across, and in no wise the "crutch" which Cohn calls it. Examples are commutation, switching, sliding contacts, and winding on of turns. It is a necessary process in every case of d-c induction.

Furthermore, in my 1929 paper, I proposed general criteria for the determination of the induced voltage to cover those peculiar cases in which it is difficult to segregate the rate of change of flux from the rate of change of flux linkages, because the effects are masked by substitutions of circuit. Those criteria stated explicitly that the total induced voltage is always the sum of the transformer and motional electromotive forces. Cohn discovered nothing new, when, in his 1949 paper,[3] he arrived at equations for the voltage identical with mine (although by a different method), and proposed identical criteria. However, Cohn did not include in his derivations anything to represent the possibility of a rate of change of flux linkages due to a change of turns (my $\phi\,dn/dt$). The number of turns n does not appear in his equations. He thus confused $d(n\phi)/dt$ with $n\,d\phi/dt$ and was forced to the unwarrented conclusion that $n\,d\phi/dt$ does not always give the induced voltage. In his final equation (Figure 9 of reference 3) he puts $d\phi/dt$ only conditionally equal to the induced voltage. His dislike of my substitution of circuit idea may stem from this.

As an illustration of the application of my general criteria for determining induced voltages, consider the "universal generator" of Figure 1. This machine consists of a revolving magnet M and a revolving segmented wheel W upon which bears a moving brush b. The rim of the wheel is broken between spokes so as to avoid eddy currents within the wheel itself. The spool s, with its slip ring and brush, performs no electrical function, but provides a means of paying out line to the moving brush b. The face of magnet M is so shaped, and its excitation is such, as to provide a flux density

$$B = (B_0 + B_2 \cos\theta_2)\cos\omega t$$

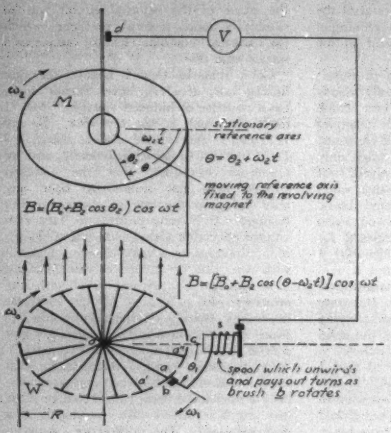


Figure 1. Universal generator

referred to the axis fixed on the magnet. Since $\theta_2=\theta-\omega_2 t$, this flux density referred to the stationary axis, is

$$B=[B_0+B_2\cos(\theta-\omega_2 t)]\cos\omega t$$

The total flux linked with the circuit $o\ a\ b\ s\ V\ d\ o$ is the flux through the pie-shaped sector $o\ a\ c$, or

$$\phi=\int_0^{\theta_1} B\frac{R^2 d\theta}{2}=\frac{R^2}{2}\int_0^{\theta_1}[B_0+B_2\cos(\theta-\omega_2 t)]\cos\omega t\,d\theta$$

$$=\frac{R^2}{2}[B_0\theta_1+B_2\sin(\theta_1-\omega_2 t)+B_2\sin\omega_2 t]\cos\omega t$$

in which $\theta_1=\omega_1 t$ for a moving brush, or constant for a stationary brush.

Now the transformer component of induced voltage is calculated by considering the motion of the conductors to be stopped ($\omega_1=0$), and the substitution of circuit to be stopped ($\omega_1=0$ or $\theta_1=$ constant). Then

$$\frac{\partial\phi}{\partial t}=\frac{R^2}{2}\Big\{-\omega[B_0\theta_1+B_2\sin(\theta_1-\omega_2 t)+B_2\sin\omega_2 t]\sin\omega t+\omega_2[-B_2\cos(\theta_1-\omega_2 t)+B_2\cos\omega_2 t]\cos\omega t\Big\}$$

The motional component of induced voltage is calculated by

$$\oint\mathbf{B}\times\mathbf{v}\cdot d\mathbf{s}=\int_0^R B\,r\omega\,dr=\frac{R^2}{2}\omega_2[B_0+B_2\cos(\theta_1-\omega_2 t)]\cos\omega t$$

The total voltage is the sum of these, or

$$e=-\left(\frac{\partial\phi}{\partial t}+\oint\mathbf{B}\times\mathbf{v}\cdot d\mathbf{s}\right)=-\frac{R^2}{2}\Big\{B_0(\omega_2-\theta_1\omega\sin\omega t)+B_2[(\omega_2-\omega_2)\cos(\theta_1-\omega_2 t)\cos\omega t+\omega_2\cos\omega_2 t\cos\omega t-\omega\sin(\theta_1-\omega_2 t)\sin\omega t-\omega\sin\omega_2 t\sin\omega t]\Big\}$$

This machine exhibits:

1. Generation by transformer action of the pulsating flux density $B_0\cos\omega t$.

2. Generation by the revolving field $B_2\cos(\theta-\omega_2 t)$.

3. Generation by moving conductors cutting the flux (ω_2).

4. Substitution of circuit as the spokes pass brush b.

5. Substitution of circuit as the turns accumulate due to the rotating brush ($\theta_1=2\pi N$).

There are innumerable special cases included by this machine, a few of which are given in Table II.

Table I. The Family Tree of Electromagnetic Induction

Rate of Change of Flux Linkages $\frac{d(n\phi)}{dt}$

Faraday's Law of Induction $e=-n\frac{d\phi}{dt}=-\frac{d}{dt}\oint\mathbf{E}\cdot d\mathbf{s}=n\frac{d}{dt}\int\int\mathbf{B}\cdot d\mathbf{S}$

Substitution of Circuit $\frac{d\phi}{dt}$

Variational Electromotive Force (Transformer Action)	+	**Motional Electromotive Force (Cutting Action)**	**No Induction**
$=\frac{\partial\phi}{\partial t}$	+	$n\oint\mathbf{B}\cdot\mathbf{v}\times d\mathbf{s}$	1. Switching
$=n\int\int\frac{\partial B}{\partial t}\cdot d\mathbf{S}$	+	$n\oint\mathbf{B}\times\mathbf{v}\cdot d\mathbf{s}$	2. Commutation
		and by Stokes theorem	3. Sliding contacts
$=n\int\int\frac{\partial B}{\partial t}\cdot d\mathbf{S}$	+	$n\int\int\nabla\times(\mathbf{B}\times\mathbf{v})\cdot d\mathbf{s}$	4. Winding on of turns
and since $\nabla\times(\mathbf{B}\times\mathbf{v})=\mathbf{B}\nabla\cdot\mathbf{v}-\mathbf{v}\nabla\cdot\mathbf{B}$ and $\nabla\cdot\mathbf{B}=0$			5. Breaking of circuit
$=n\int\int\frac{\partial B}{\partial t}\cdot d\mathbf{S}$	+	$n\int\int\nabla\cdot\mathbf{v}\,\mathbf{B}\cdot d\mathbf{S}$	
or defining vector potential A by $\mathbf{B}=\nabla\times\mathbf{A}$ and $\nabla\cdot\mathbf{A}=0$			
$=\oint n\frac{\partial A}{\partial t}\cdot d\mathbf{s}$	+	$n\oint(\nabla\times\mathbf{A})\times\mathbf{v}\cdot d\mathbf{s}$	

If the circuit is fixed ($\mathbf{v}=0$)

Rate of Change of Vector Potential $\mathbf{E}=-n\frac{\partial\mathbf{A}}{\partial t}$

Heaviside's Second Circuital Equation $\nabla\times\mathbf{E}=-n\frac{\partial\mathbf{B}}{\partial t}$

For sufficiently long periods of time

A-c or periodic voltage — No voltage induced

D-c or unidirectional voltage

Table II.

Machine	B_0	B_2	ω	ω_2	ω_1	ω_2	θ_1	Equation of Voltage
Transformer	B_0	0	ω	0	0	0	$2\pi N$	$-\pi R^2 B_0 N\omega\sin\omega t$
D-C Generator	B_0	0	0	ω_2	0	0	0	$-\frac{1}{2}R^2 B_0\omega_2$
A-C Generator (1)	0	B_2	0	0	0	ω_2	θ_1	$-\frac{1}{2}R^2 B_2\omega_2[\cos\omega_2 t-\cos(\theta_1-\omega_2 t)]$
Slip-frequency Generator	0	B_2	0	ω_2	0	ω_2	$\omega_2 t$	$-\frac{1}{2}R^2 B_2[\sin\omega_2 t\cos\omega t+(\omega_2-\omega_2)\cos(\omega_2-\omega_2)t]$
A-C Generator (2)	0	B_2	0	ω_2	ω_2	ω_2	$\omega_2 t+\pi/2$	$-\frac{1}{2}R^2 B_2\omega_2\cos\omega_2 t$
Vibrator	B_0	0	0	$\sin\omega' t$	0	0	0	$-\frac{1}{2}R^2 B_0\sin\omega' t$

REFERENCES

1. Flux Linkages and Electromagnetic Induction in Closed Circuits, **L. V. Bewley**. AIEE *Transactions*, volume 48, April 1929, pages 327–37.

2. Discussion by **L. V. Bewley** of "Calculation of Induced Voltages in Metallic Conductors," **Herbert Bristol Dwight**. AIEE *Transactions*, volume 49, April 1930, pages 453–54.

3. See reference 3 of preceding letter.

4. Letter to the Editor, **Norton Savage**. *Electrical Engineering*, volume 68, July 1949, page 645.

5. See reference 1 of preceding letter.

6. See reference 2 of preceding letter.

L. V. BEWLEY (F '47)
(Lehigh University, Bethlehem, Pa.)

NEW BOOKS

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

STEAM AND GAS TURBINES. By B. G. A. Skrotzki and W. A. Vopat. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; and London, England; 1950. 395 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, cloth, $5.00. An expansion of material originally published as special sections in the magazine *Power*, this book is of particular interest to operating engineers in the power field. It describes the general arrangement and assembly, the operating principles, the performance limitations, and the auxiliary and control devices needed for the operation and maintenance of both prime-mover types. Reheat steam turbines, automatic-extraction turbines, small-output gas turbines, regenerative-cycle units, and power-gas generators are among the types discussed. Oiling systems of all turbine types are covered in detail.

TABLE OF POWERS OF COMPLEX NUMBERS. (National Bureau of Standards, Applied Mathematics Series 8). By H. E. Salzer. For sale by Superintendent of Documents, Government Printing Office, Washington 25, D. C., 1950. 44 pages, tables, 10¼ by 8 inches, paper, $0.25. The present tables give the exact values of z^n for $z = x + iy$ where x and y each range from 0 through 10 at unit intervals, and where $n = 1, 2, \ldots 25$. Also included is a table giving the values of x^n for $x = 2$ to 9 and $n = 1$ to 25, both at unit intervals.

TABLES OF THE BINOMIAL PROBABILITY DISTRIBUTION. (Applied Mathematics Series 6). United States Bureau of Standards, Washington, D. C., 1949. 387 pages, tables, 10½ by 8 inches, cloth, $2.50 (for sale by Superintendent of Documents, Government Printing Office, Washington, D. C.). Continuing the Applied Mathematics Series, the current volume provides tables to seven decimal places of both individual terms and cumulative sums. The introduction explains the scope, method of preparation, interpolation procedure, and applications of the tables.

TRANSIENT PERFORMANCE OF ELECTRIC POWER SYSTEMS, PHENOMENA IN LUMPED NETWORKS. (McGraw-Hill Electrical and Electronic Engineering Series). By R. Rüdenberg. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England; 1950. 832 pages, illustrations, diagrams, charts, tables, 9¼ by 6¼ inches, cloth, $12.00. Based in part on a German treatise by the author, this book surveys the general field of transients in power circuits and stresses their physical behavior in preference to their mathematical development. Part *A*, on lumped linear circuits, deals with simple and magnetically-linked circuits, inertia effects of rotating masses, and the influence of the earth on lines. Part *B*, on circuits of nonlinear characteristics, deals with variable resistance, interruption by electric arcs, and magnetic saturation. A knowledge of differential and integral calculus is assumed.

VECTOR AND TENSOR ANALYSIS. By H. Lass. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England; 1950. 347 pages, diagrams, tables, 9¼ by 6 inches, cloth, $4.50. Offering a unified approach to the subject in its relationship to theoretical physics, this text acquaints the reader with the methods and tools of vector and tensor analysis as applied to geometry, mechanics, electricity, hydrodynamics, and the theory of relativity. It includes chapters on the algebra of vectors and the differential and integral calculus of vectors. A knowledge of the calculus is assumed. Worked and unworked examples are included.

ACCEPTANCE SAMPLING, a Symposium. American Statistical Association, 1108 16th Street, N.W., Washington, D. C., 1950. 155 pages, diagrams, charts, tables, 9¼ by 6 inches, paper, $1.50. This volume contains technical papers and discussions delivered at the 1946 annual meeting of the American Statistical Association. There are two papers on acceptance sampling by attributes, and two on acceptance sampling by variables. Both prepared and impromptu discussions are included.

ANTENNA THEORY AND DESIGN, 2 Volumes. By H. P. Williams. Sir Isaac Pitman and Sons, Ltd., London, England, 1950. Illustrations, diagrams, charts, tables, 8¾ by 5½ inches, linen, Volume I, 142 pages, 21s.; Volume II, 522 pages, 63s. This book provides information for the design of the great majority of antenna systems together with a brief account of the theoretical bases of the subject. Volume I deals with the fundamental theory of radiation and antennae, with emphasis on the various methods of calculating antenna characteristics. Volume II is devoted to the practical design of antennae covering the whole range of radio frequencies and also considers in detail closely allied topics such as noise sources, propagation of waves, and transmission-line characteristics. The meter-kilogram second and metric systems of units are used. Bibliographies are included in both volumes.

CHEMICAL THERMODYNAMICS. By F. D. Rossini. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1950. 514 pages, diagrams, charts, tables, 8½ by 5½ inches, cloth, $6.00. This book provides a comprehensive treatment of the subject from the fundamental laws to their applications to real physical and chemical systems. The first five chapters explain necessary background material. The next 25 chapters give a picture of modern chemical thermodynamics arranged in a logical rather than historical order. The last five chapters deal with special applications, illustrative calculations and sources of data. A knowledge of physical chemistry and some calculus is assumed.

CIRCUITS IN ELECTRICAL ENGINEERING. By C. R. Vail. Prentice-Hall, New York, N. Y., 1950. 560 pages, diagrams, charts, tables, 8¾ by 5½ inches, cloth, $7.65. Intended for use as a text for electrical engineering students, this book provides coverage of a wide variety of topics on electric circuits as well as a rigorous and fairly detailed analytical treatment of basic principles. Unusual features include a unified presentation of steady-state circuit principles that treats direct current as zero-frequency alternating current, equal emphasis on the loop and node methods of solution, and applications to both power and communications circuits. A knowledge of mathematics through calculus is assumed.

DATA ON CORROSION- AND HEAT-RESISTANT STEELS AND ALLOYS—WROUGHT AND CAST. Sponsored by A.S.T.M. Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys. (Special Technical Publication Number 52-A.) American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa., 1950. 79 pages, charts, tables, 9 by 6 inches, paper, $2.50. This publication brings up to date a previous compilation on wrought stainless alloys and includes a comprehensive new section devoted to cast alloys. It provides data on those stainless steels that have received the widest commercial usage. The data on the composition and properties of these chromium and chromium-nickel steels and alloy castings are in tabular form.

(The) EFFECTS OF ATOMIC WEAPONS, prepared for and in co-operation with the United States Department of Defense and the United States Atomic Energy Commission. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; and London, England, 1950. 456 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, linen, $3.00. Prepared under the direction of the Los Alamos Scientific Laboratory, this book summarizes present knowledge about the effect of atomic explosions. The nature of the explosion and its blast and radiation effects on people and property are considered in detail. Nuclear radiation measurement, decontamination, and protection of personnel are also among the topics discussed.

ELECTRIC FUSES. By H. W. Baxter. Longmans, Green and Company, New York, N. Y.; Edward Arnold and Company, London, England, 1950. 199 pages, illustrations, diagrams, charts, tables, 8¾ by 5½ inches, cloth, $4.00; 21s. Based on reports of research by the British Electrical and Allied Industries Research Association, this book provides data on the design, performance, and application of electric fuses. The first part deals mainly with the characteristics and properties of semienclosed fuses. The second part is devoted to the fundamentals of cartridge fuses. Discussion of transient circuit phenomena, test equipment, and fuse regulations concludes the text.

ELEKTROSTAHLERZEUGUNG (Stahleisen-Bücher, Band 9). By F. Sommer and H. Pollack. Verlag Stahleisen, Düsseldorf, Germany, 1950. 338 pages, illustrations, diagrams, charts, tables, 9¼ by 6½ inches, cloth, 34 D.M. This book reviews the latest German and American developments in the production of electrical steel and surveys German wartime advances. Following a discussion of the historical background and electrotechnical principles, refractory materials are treated. The construction of electric-arc, induction, and resistance furnaces then is detailed. This is followed by a consideration of furnace operation and metallurgical processes which occur during melting. Economic considerations and future developments also are noted.

(The) EVOLUTION OF SCIENTIFIC THOUGHT FROM NEWTON TO EINSTEIN. By A. d'Abro. Second edition, revised and enlarged. Dover Publications, New York 19, N. Y., 1950. 481 pages, illustrations, diagrams, 8¼ by 5½ inches, cloth, $3.95. Written in nontechnical language, this book reviews the history of scientific thought from the establishment of classical physics down to the theory of relativity. The essential features of Newton's great discoveries, the classical theory of absolute space and time, the contribution of Riemann and its applications by Einstein are among the major topics considered.

INDUSTRIAL ORGANIZATION AND MANAGEMENT. By L. L. Bethel, F. S. Atwater, G. H. E. Smith, and H. A. Stackman, Jr. Second edition. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1950. 851 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, linen, $5.50. This book is designed to provide a full and detailed understanding of the specialized activities of an industrial organization, large or small, their interrelationships, and the guiding principles used by management to co-ordinate and control them. In this second edition, new sections are included on production processes, waste control, plant and equipment maintenance, equipment replacement, and other matters dealing with principles of cost reduction. Case examples are used extensively throughout the book.

LINEAR INTEGRAL EQUATIONS. By W. V. Lovitt. Dover Publications, New York, N. Y., 1950. 253 pages, diagrams, tables, 8¼ by 5½ inches, linen, $3.50. The general theory of linear integral equations is presented in a systematic manner together with applications to differential equations, calculus of variations, and some problems in mathematical physics. The discussion is purposely confined to those equations which are linear and in which a single integration occurs. This edition is a reprint of a 1924 book which has been out of print for some time.

PRACTICAL TELEVISION ENGINEERING. By S. Helt. Murray Hill Books, New York, N. Y., and Toronto, Ontario, Canada, 1950. 708 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, linen, $7.50. Containing the material which practising engineers in this field need to solve everyday problems, this book presents a detailed engineering treatment of television transmitting and receiving. Theoretical and practical aspects of lenses, lighting, cathode-ray tubes, oscillographs, camera tubes, synchronizing generators, video amplifiers, regulated power supplies, and broadcasting techniques are covered. A bibliography and a set of review questions follow each chapter.

PROCEEDINGS, AMERICAN SOCIETY FOR TESTING MATERIALS, Volume 49, 1949. American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa., 1950. 1,240 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, cloth, $12.00; half leather, $14.00. This annual publication of some 1,200 pages contains technical committee reports concerning ASTM Standards and technical papers presented at society meetings, together with discussion. The table of contents and subject and author indexes cover also material published in the ASTM Bulletin and the Special Technical Publications Symposiums. The wide range of topics covered by the technical papers includes metals, cement, soils, plastics, and dielectric materials.

SUPER-REGENERATIVE RECEIVERS. By J. R. Whitehead. Cambridge University Press, American Branch, 51 Madison Avenue, New York, N. Y., 1950. 169 pages, illustrations, diagrams, charts, tables, 8¾ by 5½ inches, cloth, $4.75. This book serves as an introduction to the whole subject of superregenerative theory and design, including wartime advances. Although primarily addressed to the specialist, it is also of interest to the student and radio amateur. Both linear and logarithmic modes of operation are considered, but emphasis is on the linear mode. The final two chapters discuss automatic gain stabilization and describe a large number of superregenerative circuits.

THEORY AND DESIGN OF ELECTRON BEAMS. By J. R. Pierce. D. Van Nostrand Company, Toronto, Ontario, Canada; New York, N. Y.; London, England, 1949. 197 pages, illustrations, diagrams, charts, tables, 9¼ by 6 inches, cloth, $3.50. This book on electron optics contains the theoretical material necessary for a good understanding of electron flow and electron focusing in devices other than the electron microscope and image tubes. Emphasis is on space charge and thermal velocities. Problems are placed at the end of each chapter, and references are included as footnotes.

WAVE GUIDES. (Methuen's Monographs on Physical Subjects.) By H. R. L. Lamont. Third edition. John Wiley and Sons, New York, N. Y.; Methuen and Co., Ltd., London, England, 1950. 118 pages, diagrams, charts, tables, 6¾ by 4¼ inches, cloth, $1.50. Of interest to both students and practising engineers, this book briefly presents the essential parts of the theory of wave guides. It considers general transmission theory, attenuation and stability of waves, wave guides as resonators and radiators, and rectangular guide techniques. The classified bibliography contains many references on the experimental side of the subject.

WAVE FILTERS. (Methuen's Monographs on Physical Subjects). By L. C. Jackson. Third edition. John Wiley and Sons, New York, N. Y.; Methuen and Co., Ltd., London, England, 1950. 107 pages, diagrams, charts, tables, 6¾ by 4¼ inches, cloth, $1.25. This book provides an account of the properties of electric wave filters for students of physics and radio. The general properties of wave filters, constant-k filters, m-derived filters, and composite filters are discussed. The effect of resistance on the performance of filters is considered, as well as their design and construction. Mechanical and acoustic applications are included.

WAVE MECHANICS, Elementary Theory. Second edition. 312 pages, $3.50. WAVE MECHANICS, Advanced General Theory. 524 pages, $5.00. By J. Frenkel. Dover Publications, New York, N. Y., 1950. Diagrams, charts, tables, 8¼ by 5⅓ inches, linen. This is the first American printing of a 2-volume set published in England in 1934 and 1936. The first volume gives a general survey of wave mechanics and quantum statistics using only elementary mathematics. The second volume is devoted to the mathematical development of the general ideas underlying the subject and connects it with classical mechanics. Only the most essential elements of the theory are considered. References for each chapter are given at the end of the book.

A.S.T.M. STANDARDS ON PLASTICS, Specifications, Methods of Testing, Nomenclature, Definitions. Sponsored by A.S.T.M. Committee D-20 on Plastics, June, 1950. American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa. 1,076 pages, illustrations, charts, tables, 9 by 6 inches, paper, $4.85. Some 120 specifications and test methods are presented covering a wide range of subject matter. The separate standards are classified broadly under the following headings: specifications for plastics; strength, hardness, thermal, optical and permanence properties; analytical methods for plastics; molds and molding processes; conditioning; electrical tests; sheets, tubes, rods and molded insulating materials; definitions and nomenclature.

ANTENNAS. By J. D. Kraus. McGraw-Hill Book Co., New York, N. Y.; Toronto, Ontario, Canada; London, England, 1950. 553 pages, illustrations, diagrams, charts, tables, 9¼ by 6¾ inches, fabrikoid, $8.00. Written from the electromagnetic theory viewpoint, this book presents the basic theory of antennas with emphasis on their engineering applications. The principles given apply to antennas of all frequencies. The first four chapters deal with the fundamental theory of point sources and of the antenna as an aperture. The various types of antennas are then treated in detail. A knowledge of elementary electromagnetic theory, transmission lines and wave guides, and vector analysis is assumed. Problems and a bibliography are included.

APPLIED ELECTRICITY. By E. Hughes. Longmans, Green and Co., London, England; New York, N. Y.; Toronto, Ontario, Canada, 1950. 412 pages, diagrams, charts, tables 7½ by 5 inches, fabrikoid, $2.25. Basic information is provided on a wide range of subjects in the electrical field, with emphasis on the necessary calculations for work within the fields considered. Topics covered are electromagnetism, electrostatics, d-c machinery, single-phase and three-phase circuits, transformers, a-c motors and generators, thermionics, electric lamps and illumination. Although vector diagrams are used consistently for solutions of a-c circuits, the final chapter gives an explanation of the use of symbolic notation.

ATOMIC PHYSICS. By W. Finkelnburg. McGraw-Hill Book Co., New York, N. Y.; Toronto, Ontario, Canada; London, England, 1950. 498 pages, illustrations, diagrams, charts, tables, 9¼ by 6¾ inches, cloth, $6.50. A translation and minor revision of the author's German text, this book provides a systematic treatment of the whole field of nuclear, atomic, molecular and solid-state physics. It starts at a comparatively low level and provides a basis for an understanding of important theories, empirical facts, unsolved problems, and present trends of research in the field.

ELECTRIC WINDERS. By H. H. Broughton. Second edition. E. & F. N. Spon Ltd., 57 Haymarket, London, England, S. W. 1, 1948. 451 pages, diagrams, charts, tables, 9¾ by 7½ inches, fabrikoid, 63s. Intended primarily for the engineering staffs of coal and metalliferous mines, this volume is also of interest to those who design, construct and operate mine hoisting equipment. In this edition, the first since 1927, nearly the whole text is rewritten, and seven new chapters are added. The new material is on Koepe-pulley winders, deep-level winding, intensive hoisting, skip-hoisting of coal, etc. Of special note are the large number of tables and detail diagrams, detailed accounts of failures, and the chapter bibliographies.

ELECTRICAL ENGINEERS' HANDBOOK, Electric Communication and Electronics. (Wiley Engineering Handbook Series). Edited by H. Pender and K. McIlwain. Fourth edition. John Wiley & Sons, New York, N. Y.; Chapman & Hall, Ltd., London, England, 1950. Sections separately paged, illustrations, diagrams, charts, maps, tables, 8½ by 5½ inches, cloth, $8.50. The new edition of this standard handbook, prepared by seventy-eight specialists, is entirely rewritten to reflect the rapid widening of the electronics field. In particular, frequency modulation and all the pulse techniques in both the communication and radar fields are now covered for the first time as are radio aids to navigation. The range of topics covered is demonstrated in the section headings which include mathematics and symbols, properties of materials, electron tubes, circuit elements, electrical instruments and measurements, acoustics and acoustical devices, optics and optical devices, telephony, telegraphy, television, and medical applications of electricity.

ELECTRICAL INSTALLATION WORK. By T. G. Francis. Longmans, Green and Co., London, England; New York, N. Y.; Toronto, Ontario, Canada, 1950. 232 pages, illustrations, diagrams, charts, tables, 8¼ by 5¼ inches, cloth, 12s 6d. This book is written for those engaged in electrical installation who desire to learn something of the technical side of their work. It covers supply systems, consumer's circuits, conductors and cables, wiring systems and accessories, grounding, instruments and measuring, illumination, electric heating, a-c and d-c machines, primary and secondary cells, electric bells, and telephones.

ELECTRONIC ENGINEERING MASTER INDEX, January through December, 1949. Electronics Research Publishing Company, 480 Canal St., New York, N. Y., 1950. 296 pages, 10 by 7 inches, cloth, $17.50. This book, the fourth volume in a series that starts with the 1925–1945 issue, indexes 8,500 articles from nearly 400 world-wide scientific periodicals, journals, proceedings, and technical house-organs for the year 1949. 4,000 applicable United States patents are listed with the articles under classified headings. Declassified United States, British, and Canadian documents are included as well as British and American reports on German and Japanese research and developments. There is a bibliography of textbooks on electronics and allied subjects. The cumulative cross index of subjects serves as a guide to this and the previous editions.

ENGINEERING ECONOMY. By H. G. Thuesen. Prentice-Hall, New York, N. Y., 1950. 501 pages, diagrams, charts, tables, 8½ by 5¾ inches, cloth, $6.65. The importance of considering thoroughly the economic as well as the technical aspects in the solution of engineering problems is stressed throughout the book. To this end the several chapters deal with the basic mathematical factors, the treatment of estimates, various kinds of costs and accounting methods, bases for comparison of alternatives, evaluation of replacements, economy of operations, utilization of personnel, and the application of engineering economy studies to public activities. Illustrative numerical examples are extensively used.

FATHER OF RADIO, the Autobiography of Lee de Forest. Wilcox & Follett Co., Chicago, Ill. 1950. 502 pages, illustrations, diagrams, 9¼ by 6 inches, cloth, $5.00. This book is the life story of one of our most interesting and versatile geniuses. It covers his childhood and youth, his early struggles and achievements in wireless telegraphy, his rivalry with Marconi, his invention and development of the basic instruments of radio broadcasting, and his relations with other great scientists. A list of the de Forest patents from 1902–1949 is included.

PAMPHLETS • • • • •

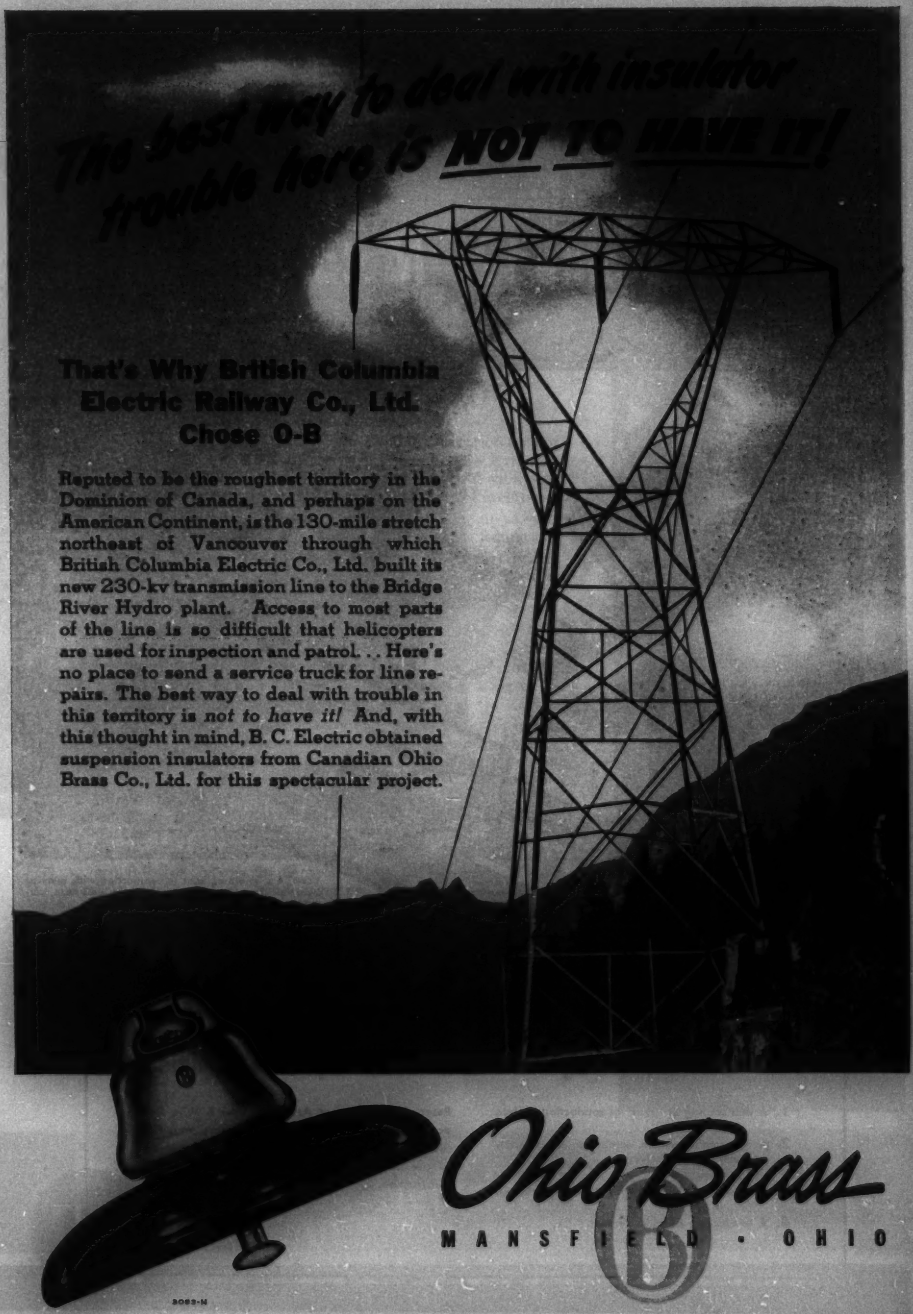
The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Bibliography on Non-Metallic Bearings Compiled by the Engineering Societies Library, this bibliography of 101 selected references covers all aspects of nonmetallic bearings such as their manufacture, design, properties, wear, lubrication, performance, testing and applications, particularly of bearings made of rubber, wood, laminated phenolic plastics, resin-impregnated cotton fabric, micarta, and nylon. Applications discussed are for rolling mills, marine propeller shafts and rudder posts, automatic presses, axle bearings for railroad rolling stocks, agricultural machines, and so forth. This "ESL Bibliography Number 6" may be purchased from the Engineering Societies Library, 29 West 39th Street, New York, N. Y., for $2.00.

Air Conditioner Rating Standard. This standard for testing and rating air conditioners has been issued by the American Society of Refrigerating Engineers (ASRE). It covers self-contained air conditioners, room air conditioners, remote type air conditioner heat pumps, and oil- and gas-fired air conditioners. This standard consists of two former ASRE Standards, Number *16*, Methods of Rating and Testing Self Contained Air Conditioning Units for Comfort Cooling (1940), and Number *13*, Methods of Rating and Testing Air Conditioning Equipment (1936). Copies of Standard *16–R* may be obtained from the American Society of Refrigerating Engineers, 40 West 40 Street, New York 18, N. Y., at $1.00 per copy.

Lighting for Bakeries. A new report of the Illuminating Engineering Society covers lighting requirements necessary to efficient and economical production processes in bakeries. Complete with photographs, the report shows lighting fixtures suitable for baking establishments and correct lighting layouts. Sections include a table of lighting levels for the various work areas; recommendations for paint colors for walls and ceilings; descriptions for use of natural lighting; and a section on maintenance of lighting equipments. The report concludes with a detailed appendix on the use of ultraviolet radiation to control mold contamination. This 16-page booklet is available upon request from the Publications Office, Illuminating Engineering Society, 51 Madison Avenue, New York 10, N. Y. at $0.50 per copy.

American Concrete Institute 20-Year Index. The American Concrete Institute (ACI) has published this index to replace the ACI 10-Year Index (1947), extending that coverage from November 1929 to June 1949. It includes all the papers published since 1929 in the ACI Journal and ACI special publications. The index is priced at $2.00 and may be ordered from the American Concrete Institute, 18263 West McNichols Road, Detroit 19, Mich.



That's Why British Columbia Electric Railway Co., Ltd. Chose O-B

Reputed to be the roughest territory in the Dominion of Canada, and perhaps on the American Continent, is the 130-mile stretch northeast of Vancouver through which British Columbia Electric Co., Ltd. built its new 230-kv transmission line to the Bridge River Hydro plant. Access to most parts of the line is so difficult that helicopters are used for inspection and patrol. . . Here's no place to send a service truck for line repairs. The best way to deal with trouble in this territory is *not to have it!* And, with this thought in mind, B. C. Electric obtained suspension insulators from Canadian Ohio Brass Co., Ltd. for this spectacular project.

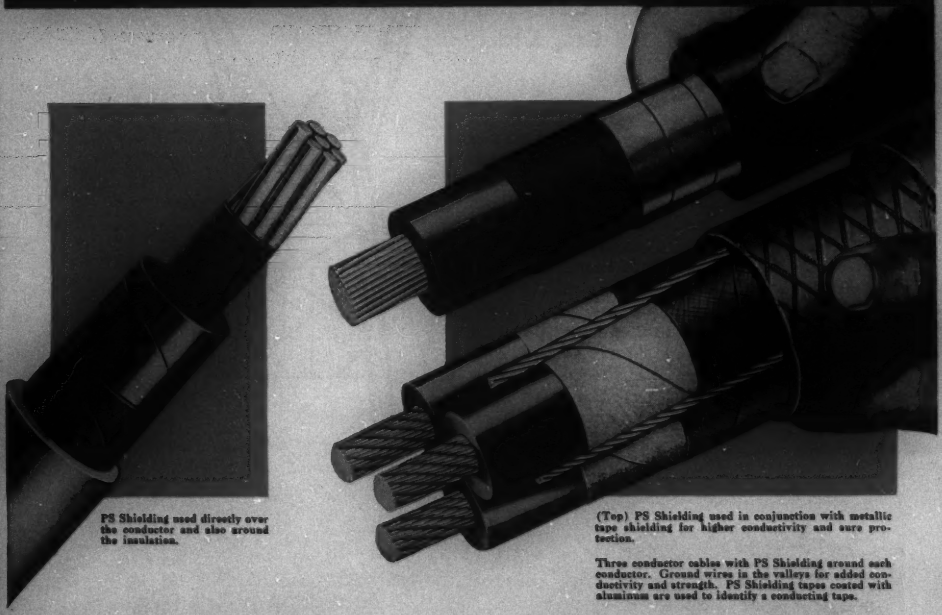
Ohio Brass

MANSFIELD · OHIO

2062-M

What type of power cable

Unshielded? Metallic Shielded?



PS Shielding used directly over the conductor and also around the insulation.

(Top) PS Shielding used in conjunction with metallic tape shielding for higher conductivity and sure protection.

Three conductor cables with PS Shielding around each conductor. Ground wires in the valleys for added conductivity and strength. PS Shielding tapes coated with aluminum are used to identify a conducting tape.

Forms of PS Shielding

1. A thin coating or "skin" of conducting rubber.
2. A substantial sheath combining conductivity and mechanical protection.
3. A fibrous tape coated with conducting rubber.
4. A conducting paint or cement.

Who developed PS Shielding?

Research engineers at American Steel & Wire Company pioneered in this field many years ago. Since then, numerous other companies have been licensed to use conducting rubber tapes in electrical cable construction.

shall I use—
Non-Metallic PS Shielding?

● This subject has frequently come up for deliberation among outstanding power transmission engineers. They have thrown considerable light on the question and any buyer of cable will want to weigh the advantages and disadvantages of each type.

Unshielded insulated cable can generally be used up to 5000 volts without much trouble from corona and ozone formation.

Metallic Shielding in the form of metal tapes, wire braids and wire servings has been used with success under favorable conditions for cables 5000 volts and up. However, lack of flexibility may cause serious trouble. With expansion and contraction, bending and straightening, the metal shield tends to separate slightly from the insulation forming air gaps. Each air gap is a potential danger point causing spark discharges with corona and ozone formation—highly deteriorating to an organic insulating material.

Non-metallic PS Shielding with conducting tapes for cables 5000 volts and up, eliminates many of the weaknesses of metallic shielding. PS Shielding consists of a fibrous tape coated with a conducting rubber. It stays flexible—remains in intimate contact with the conductor or insulation. No air gaps can form and destructive sparkling is prevented. Corona is definitely eliminated—and so is ozone.

Type PS Shielding may be used alone, in combination with ground wires, or as a supplement to metallic shielding. We are now able to offer a conducting rubber compound that will provide improved shielding for any type of high-voltage cable.

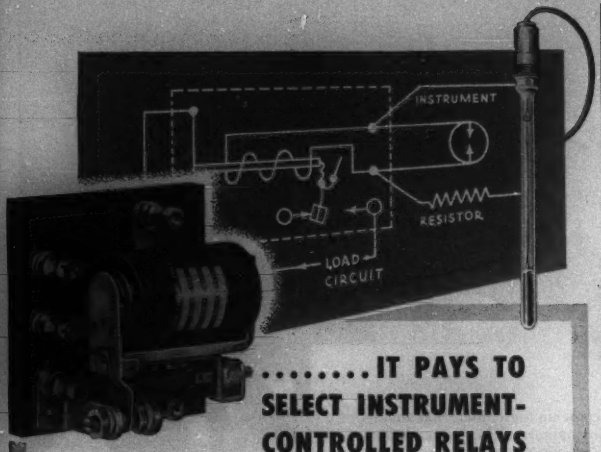
Write for our booklet, "Type PS Semi-Conducting Shielding" which gives complete information.

AMERICAN STEEL & WIRE COMPANY, GENERAL OFFICES: CLEVELAND, OHIO
COLUMBIA STEEL COMPANY, SAN FRANCISCO
TENNESSEE COAL, IRON & RAILROAD COMPANY, BIRMINGHAM, SOUTHERN DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS

American Electrical Wire and Cable

UNITED STATES STEEL



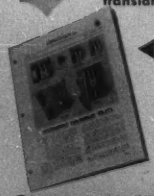
.....IT PAYS TO SELECT INSTRUMENT-CONTROLLED RELAYS

from this Complete line!

25 standard Struthers-Dunn types match over 90% of all normal requirements in the exacting field of instrument-controlled relays. Moderately priced, they'll prove doubly economical in your production because a type can be selected to match both your electrical and mechanical requirements *exactly*.

Available relays cover applications:

- where load voltage exceeds the rating of sensitive instrument contacts
- where high load current may shorten instrument contact life
- or where 3-wire (HCL) instrument control must be translated into 2-wire "off" and "on" control.



◀ GET THIS HANDY GUIDE

Write for Data Bulletin 6100 for complete information on relays for 2-wire instruments including mercurial thermostats; and relays for 3-wire high or low-voltage instruments.

STRUTHERS-DUNN

5,348 RELAY TYPES

STRUTHERS-DUNN, INC., 150 N. 13th Street, Philadelphia 7, Pa.

BALTIMORE • BOSTON • BUFFALO • CHARLOTTE • CHICAGO • CINCINNATI CLEVELAND • DALLAS • DETROIT • KANSAS CITY • LOS ANGELES MINNEAPOLIS • MONTREAL • NEW ORLEANS • NEW YORK • PITTSBURGH • ST. LOUIS • SAN FRANCISCO • SEATTLE • SYRACUSE • TORONTO

INDUSTRIAL NOTES ....

Allis-Chalmers Rumley Ltd. Acquires Erie Iron Works. Allis-Chalmers Rumley Ltd., a Canadian subsidiary of the Allis-Chalmers Manufacturing Company, Milwaukee, Wis., has announced the purchase of the plant of the Erie Iron Works at St. Thomas, Ontario, Canada, and also the purchase from that city of an additional seven acres of land. The General Machinery Division of the parent company plans to manufacture and assemble products that will become component parts of finished equipment. Foremost among these will be controls for diesel locomotives manufactured by the General Motors diesel plant of London, Ontario, Canada.

Cornell-Dubilier Purchases Assets of the U. S. Devices Corp. The Cornell-Dubilier Electric Corporation and its subsidiary, the Radiart Corporation, have purchased the assets of the U. S. Devices Corporation of South Plainfield, N. J. The U. S. Devices rotator has been added to the Cornell-Dubilier tele-rotor line under the name of the "Standard" tele-rotor.

RCA Acquires New Plant. The RCA Victor Division of the Radio Corporation of America has acquired a new plant in Cincinnati, Ohio, for the manufacture of miniature-type electron receiving tubes. The plant, to be operated by the RCA Tube Department, is scheduled to be in full production by the autumn of 1951.

Minnesota Mining Buys Big Rock Stone and Material Company. The Minnesota Mining and Manufacturing Company has purchased the Big Rock Stone and Material Company in Little Rock, Ark. The sale included Big Stone quarry in North Little Rock and the general offices and retail plant for crushed stone, sand, and ready-mix concrete. R. S. Wilson, Sr., President of Big Rock Stone and Material Company, will continue as active head of the company's management, which will operate as a wholly owned subsidiary of the Minnesota Mining organization.

Sola Electric Appoints New Sales Representative. Appointment of the Slaybaugh and Thompson Company, 100 West 13th Avenue, Denver, Colo., as its sales representative for the mountain states area has been announced by the Sola Electric Company, Chicago, Ill. The new agent will handle the entire Sola line in the states of Colorado, Wyoming, Utah, Idaho, and New Mexico.

(Continued on page 26A)

OHMITE...

World Renowned for Dependability

To thousands of equipment manufacturers the world over—the name OHMITE has become synonymous with *QUALITY*. These manufacturers have put OHMITE resistance products through the most rigid of all tests—performance in the field—and these superior units have provided consistently dependable performance and long life under the most difficult operating conditions.

"Be Right with OHMITE" is more than just a slogan to these users. They know that when they specify OHMITE, they get the finest resistance equipment available—anywhere!

WRITE on company letterhead for catalog and engineering manual No. 40

OHMITE MFG. CO.
4903 Flournoy St.
Chicago 44, Ill.

25th Anniversary
1935-1960

Be Right with **OHMITE**
Reg. U. S. Pat. Off.

RHEOSTATS RESISTORS TAP SWITCHES

Check these exclusive features of L&N Voltage and Power Factor Recorders

Multiple-Point A-C Voltage Recorder With Suppressed Range, Extra Readability

Wherever highly legible and accurate records of a-c voltage are required—for feeder or bus regulation or for control of reactive power flow—Micromax and Speedomax instruments offer exceptional features:

1. Suppressed-zero range discards the part of the voltage scale that the operator doesn't need to watch, and spreads the few volts or kilovolts in which he is interested across the instrument's entire chart width of 9⅞ inches. Thus for a nominal 115-volt circuit, you can choose a range of 90 to 130 volts, easily readable to ½ volt.

2. A single Micromax or Speedomax instrument records voltages on as many as sixteen separate feeders—reduces instrument cost because one recorder does the work of several. Related voltages can be readily compared on the same chart.

3. Recorder can be installed remote from the metering point, because the instrument is a d-c potentiometer and draws no current from the thermal converter metering element.

Standard ranges are supplied for the usual bus, transmission and distribution voltages.

A-C voltage recorder (Speedomax 6-point model is shown above) has square-law scale which adds to readability at upper portion of range.

Standard range for strip-chart Micromax Power Factor Recorder is 0.5 lead to 0.5 lag. Note legibility of record on 9⅞ inch wide chart.

Power Factor Totalized on 3-Phase Feeders

Industrial power consumers obtain accurate records of power factor on 3-phase circuits, by means of Micromax Recorders . . . with these outstanding advantages:

1. A single instrument can show the power factor of total load on a multiplicity of feeders. Where a number of power lines supply a plant's needs, the Micromax instrument measures and records power factor of plant load for all purchased power.

2. The recorder can be located hundreds of feet from the metering point . . . wherever its information can be utilized most effectively.

Both of these characteristics come from the unique measuring method which is employed. The metering device, a standard two-element thermal converter, is connected in the three-phase circuit being measured. The Micromax Recorder is a d-c null-balance potentiometer calibrated directly in per cent power factor. To totalize several feeders, the thermal converter outputs simply are connected in series and wired to the recorder.

For further information write to Leeds & Northrup Co., 4962 Stenton Avenue, Philadelphia 44, Pa.

MEASURING INSTRUMENTS • TELEMETERS • AUTOMATIC CONTROLS • HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Jrl. Ad ND4-51(1)

Lionel has satisfied itself that through Quinterra, they have a step-down transformer that is virtually harm-proof for their customers of all ages.

The LIONEL CORPORATION

FACTORIES AND SERVICE DEPT. SAGER PLACE · IRVINGTON 11, N. J.

Johns-Manville, Inc.
270 Madison Ave.
New York, N. Y.
Att: Mr. B. B. Woodford

September 29, 1949

We believe that you will be interested to learn of our experience with "Quinterra" insulating sheet.

The Lionel Corporation has been using "Quinterra" as insulation between the primary and secondary windings of our toy transformers almost from the first day that this material was commercially available.

Due to its superior mechanical strength, its high insulating properties, and especially its resistance to charring even under burn-out tests, short circuits and leakage between the two windings have been entirely eliminated. The user of the transformer can now be assured of perfect safety from 110-volt shock even though through some mishap he has burned out the transformer.

It should be a source of gratification to the developers of this material to know that they have made an important contribution to the safety of electrical devices both large and small.

Yours very truly

THE LIONEL CORPORATION

Joseph L. Bonanno
Chief Engineer

jlb:nr
enc.

"Railroad" discovers *Quinterra* insulation adds new safety factor for customers

REPORT AFTER REPORT from users of Quinterra shows that this revolutionary, new Johns-Manville purified asbestos high-temperature electrical insulation is effecting major improvements in transformer design.

And more than that. These reports show that manufacturers are not only obtaining important sales advantages for their electrical products through the use of Quinterra . . . but they are also saving time and money in their manufacturing operations, as well!

This paper-thin, continuous sheet insulation is being widely used in transformers and coils. Its lasting dielectric strength, due to its resistance to pyrolysis, assures a greater safety factor and longer operating life. Quinterra withstands substantially higher temperatures than the hot-spot limit of 130C for Class B insulations.

QUINTERRA

- ✓ **cuts factory rejects**
- ✓ **reduces complaints**
- ✓ **improves production rate**
- ✓ **produces more uniform product**
- ✓ **cuts costs of operations**

Johns-Manville ELECTRICAL INSULATIONS

Johns-Manville
Box 290, New York 16, N. Y.

Kindly send me a copy of
Johns-Manville Quinterra Electrical Insulation EL-34A.

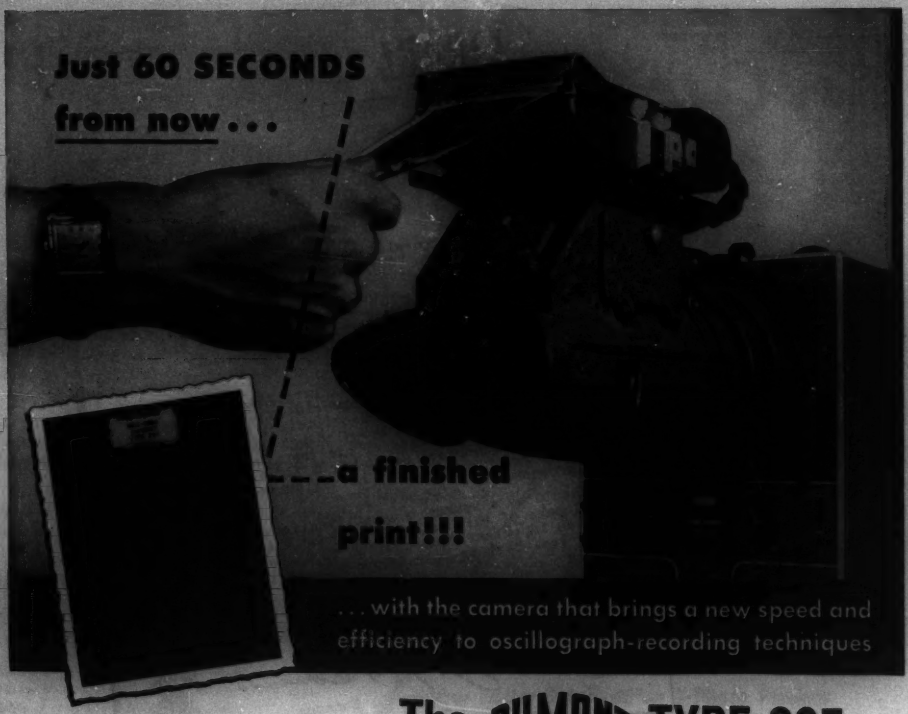
Name_____

Company_____ Position_____

Address_____

City_____ State_____

EE-12


Just 60 SECONDS
from now . . .
. . . a finished
print!!!
. . . with the camera that brings a new speed and
efficiency to oscillograph-recording techniques

The DUMONT TYPE 297

Oscillograph-record Camera

To the many advantages offered by the cathode-ray oscillograph in observing electrical phenomena in the making, there is now added a permanent recording means.

Du Mont now offers a complete choice of oscillograph-record cameras for cathode-ray oscillography. Simplest of all in operation is the Du Mont 297 which produces a finished print in just 60 seconds. This camera utilizes the Polaroid-Land "packaged" developing process. Once you've snapped the shutter, it's self-contained developing process lets you forget the troubles and variables of the darkroom.

Regardless of what your electrical specialty may be, Du Mont cathode-ray oscillography can prove of immeasurable value in quicker, simpler, better observations—plus permanent recordings, when desired.

SPECIFICATIONS

LENS—Du Mont-Wollensak f/2.8 or f/1.9, 75mm, coated.

SHUTTER — Wollensak Alphax; shutter speeds of 1/25, 1/50, 1/100 sec. Time and Bulb.

FOCUS—Fixed. May be adjusted for special oscillographic work.

WRITING SPEED—Writing rates of 3.5 in usec. have been recorded consistently at 12,000 volts accelerating potential.

PRINT SIZE—3¼ x 4 ¼ in.—one, two, three, or more exposures per print.

IMAGE REDUCTION RATIO—2.25:1.

PHYSICAL SIZE—Length, 14⅝ in.; height, 10 in.; width, 6 in.

WEIGHT—12 lbs.

PRICE . . . . . $285.00 with f/2.8 lens
$355.00 with f/1.9 lens

Write for bulletin on photographic techniques.

. . . and for thrifty SINGLE-FRAME recording

THE DU MONT TYPE 296

Oscillograph-record Camera

The Type 296 is an inexpensive oscillograph-record camera, greatly improved for general-purpose application with any standard 5-inch cathode-ray oscillograph. It incorporates a compact, all-metal, 35mm camera, calibrated shutter and a high-quality f/2.8, 75mm, coated lens which increases its capability 57% over the Type 271-A which it supersedes. Construction is rugged and durable; operation simple and foolproof. The Type 296 weighs only 4½ lbs.

PRICE . . . $149.50

ALLEN B. DU MONT LABORATORIES, INC., INSTRUMENT DIVISION 1200 MAIN AVENUE CLIFTON, NEW JERSEY

NO OVERHEATING . . .
LESS OXIDATION . . .
YOU SAVE 10—15% WITH

SILVER CONTACT SURFACES AT NO INCREASE IN PRICE

POWER CONNECTORS

SILVER is used exclusively on *all* General Electric connectors because it allows power to flow between conductor and connector with minimum losses, and avoids overheating.

Maintenance is reduced, since there is no troublesome copper-oxide formed. Oxide formation causes overheating which in turn hastens oxidation; a vicious cycle that may cause the connector to fail. When you use G-E connectors with silver contact surfaces, the cycle can't even get started.

CORRECT MATERIAL for the job is another feature assuring you that G-E connectors "run cool." The composition of the alloy used permits the connectors to carry the maximum current of any conductor . . . cable, tubing or rod . . . without overheating.

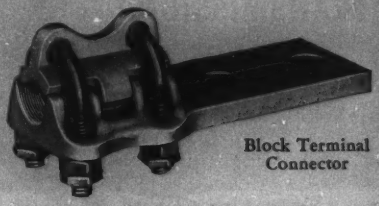
By using General Electric connectors you're assured of long connector life because of silver contact surfaces and correct material for the job—double safeguards against oxidation troubles, and they don't cost you a cent extra.

CHECK THESE ADDITIONAL FEATURES . . .

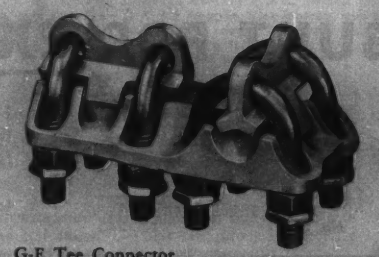
SERRATED CONTACT SURFACES give high grip strength and a permanent, high-conductivity joint that will resist vibration and give positive pressure on the conductor at all times.

NON-CORRODIBLE HARDWARE is of high-strength bronze alloy that maintains pressure during long service. G-E connectors will not twist, distort, or season crack.

INTERLOCKING SIDES confine the conductor within the connector enclosure, thus obtaining full advantage of the conductor's current-carrying capacity.



Block Terminal Connector



G-E Tee Connector

Place an order today with your G-E sales representative and start realizing the many benefits to be gained by using General Electric connectors. Also, write for a copy of publication GEC-400 that contains 40 pages of valuable information on G-E connectors, and see for yourself how easy they are to order. Write to *Apparatus Dept., Section 856-55, General Electric Company, Schenectady 5, N. Y.*

GENERAL ELECTRIC

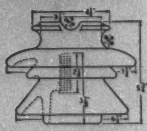
ANOTHER VICTOR INSULATOR THAT SAVES AS IT SERVES

VICTOR

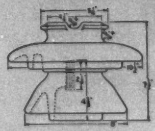
TRANSMISSION PINTYPE INSULATORS

No. 245

BUILT FOR EXTRA LONG LIFE!



No. 127



No. 245

VICTOR Catalog No.		127	245
Nominal Voltage Rating		27	45
60 cycle dry flashover	KV.	95	125
60 cycle wet flashover	KV.	60	80
Dry arcing distance	In.	7	9½
Leakage distance	In.	13	21
Pinhole diameter	In.	1⅜	1⅜
Cantilever strength	Lbs.	2,500	3,000
RNI (plain)	MV.	8,000	14,000
RNI (radio-freed)	MV.	100	200
1000 KC at applied	KV.	15	30

FACTS—*actual performance data* obtained from installations throughout the country—prove that VICTOR transmission pintype insulators *retain* their original high standards after *years and years* of severe service on the job. This means *extra* years of trouble-free insulator service.

The extra service-years you get in *every* VICTOR pintype insulator are a result of such built-in features as: Construction of the *best* high voltage porcelain, a rugged, *self-cleaning* design, and a *special "cushion" coating* at the joining surfaces that *eliminates* problems caused by thermal expansion.

Reap the benefits of long, dependable service—*standardize* on VICTOR transmission pintype insulators.

For more information consult our new Condensed Catalog No. 4, write us, or call your VICTOR representative.

VICTOR INSULATORS Inc.

VICTOR, NEW YORK

Look for this trade mark of enduring service

V

A 1000 kva power transformer ready to receive sound level tests in Allis-Chalmers Pittsburgh Works sound laboratory. Laboratory walls of concrete, glass wool and acoustical tile exclude 99.98% of exterior noise power.

Here a distribution transformer is getting sound and harmonic analysis. Physical noise level and harmonic index are new tools to measure sound energy. Transformer designs, in addition, are tested in accordance with ASA and NEMA standards.

Quiet Neighborhoods NEED QUIET TRANSFORMERS

How to Beat Transformer Noise—That's The Problem Allis-Chalmers Engineers Are Tackling In Their Pittsburgh Sound Laboratory

TODAY'S DEMAND FOR quieter transformers is stronger than ever before. Larger rated transformers are moving into residential areas as distribution systems grow up. That's why holding customer good will depends more and more on keeping transformer sound level low.

What is Allis-Chalmers doing about sound level? In cooperation with sound experts, Allis-Chalmers engineers are conducting research on new electrical core steels in an effort to reduce magneto-striction and resonance. They're testing effects of clamping pressures, core impregnation and anchoring of core and coil assembly. Their laboratory is specially equipped for sound level experiments.

What will be the result? Transformers that create good will. Research, engineering and production are teaming up at Allis-Chalmers to give you a transformer that is truly a good neighbor.

For details on Allis-Chalmers transformers contact your nearby A-C sales office or write for bulletins:

Bulletin 61B7309A — *ACP* (Allis-Chalmers self-protected) distribution transformers.

Bulletin 01B6168B — Complete A-C power and distribution line.

Bulletin 61B6014A — Substation transformers, 50 to 500 kva.

A-3170

ALLIS-CHALMERS, 931A SO. 70 ST.
MILWAUKEE, WIS.

ACP (Allis-Chalmers Protected) is an Allis-Chalmers trademark.

ALLIS-CHALMERS

A page from the note-book of Sylvania Research

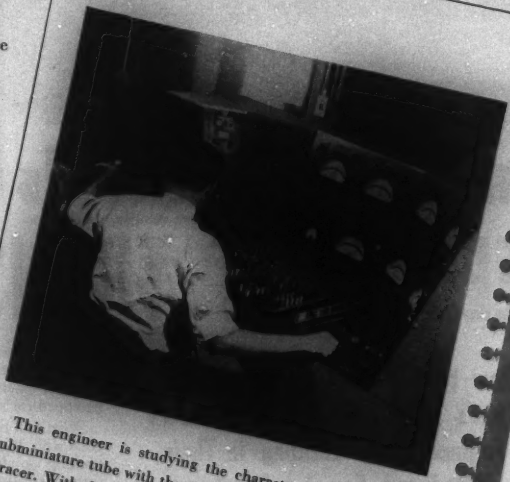
New Sylvania instrument speeds tracing of receiving tube curves

Families of characteristic curves of electronic tubes, complete with all horizontal and vertical graph lines, are automatically traced on a cathode ray tube face and photographed with this new Sylvania-engineered equipment.

Precise calibration is assured by automatic compensation for circuit nonlinearities and tracing errors.

Rapid operation yields accurate data even in regions of high current operation as encountered in Class C and pulse applications. This instrument, result of years of Sylvania development and research, provides tube engineers with more accurate evaluation of new designs. Radio and television circuit designers gain from it better application data over a wider range of applied voltages.

It marks one more Sylvania advance toward better product performance—better design—better service.



This engineer is studying the characteristic curves of a subminiature tube with the new Sylvania Cathode-ray Curve Tracer. With this instrument he quickly obtains families of curves for more accurate data about tube behavior under a wide variety of conditions.

SYLVANIA ELECTRIC

ELECTRONIC DEVICES; RADIO TUBES; TELEVISION PICTURE TUBES; ELECTRONIC TEST EQUIPMENT; FLUORESCENT TUBES, FIXTURES, SIGN TUBING, WIRING DEVICES; LIGHT BULBS; PHOTOLAMPS; TELEVISION SETS

Close Tolerances

IN O-B THOREX ARRESTERS OFFER LARGE Savings

To assure the extremely close operating tolerances offered in the new O-B Thorex lightning arrester, factory production must be somewhat better than published values. To guarantee an IR discharge voltage not exceeding + 5% and a sparkover voltage not exceeding + 10% in a mass-produced item requires daily manufacturing performance well within these outside permissible allowances. Hence, two important words precede O-B's tolerance statement: "Less than . . ."

What is this really worth? The low average IR discharge rating of Thorex arresters, coupled with a voltage tolerance of only + 5% and the rapid sparkover with only a + 10% tolerance, provide a new low level of apparatus insulation protection. You can take advantage of such protection by specifying O-B Thorex arresters on new apparatus as well as old. The Thorex brings to the American market the minimum values of protective characteristic tolerance so far offered. Minimum tolerance added to low average values of sparkover and IR discharge voltage spell improved protective margin.

This is only one phase of the story behind the new O-B Thorex valve type lightning arrester. A new book, Publication 869-H, describes the Thorex in detail. Write for a copy or contact your O-B representative who will gladly supply any information you require.

THOREX

valve type LIGHTNING ARRESTERS give you...

1. Low average IR discharge voltage with less than + 5% tolerance.
2. Low average sparkover voltage with less than + 10% tolerance.
3. Discharge capacity of 100,000 amperes. *
4. Duty cycle of 10,000 amperes. *

* According to AIEE Standard, 28-A

Ohio Brass

MANSFIELD • OHIO

WHEN YOU NEED A MINIATURE TRANSFORMER

CHECK THESE FEATURES OF THE HORNET

SIZE AND WEIGHT Because they are designed for high operating temperatures, Hornet Transformers and Reactors have only about one-fourth the size and weight of Class A units of comparable rating.

VOLTAGE RATINGS Designs are available for RMS test voltages up to 10,000 volts at sea level, and up to 5,000 volts at 50,000 feet altitude. Power ratings from 2VA to 5KVA.

POWER FREQUENCIES These units are designed to operate on 380/1600 cps aircraft power supplies, 60 cps power supplies, and any other required power frequency.

AMBIENT TEMPERATURES Hornet Units can be designed for ambient temperatures up to 200 deg. C. Size for any given rating depends upon ambient temperature and required life.

LIFE EXPECTANCY Extensive tests indicate that the life expectancy of Hornet units at continuous winding temperatures of 200 deg. C. is over 50,000 hours.

MOISTURE RESISTANCE Since Hornet Transformers and Reactors contain only inorganic insulation, they are far more moisture resistant than conventional Class A insulated units.

EFFICIENCY Regulation and efficiency of Hornet Transformers compare favorably with Class A units.

SPECIFICATIONS Hornet Transformers meet the requirements of Government specifications covering this type of equipment.

Bulletin B300, containing full electrical and dimensional data on Hornet units, is now available. Write for it, or tell us your specifications for special units.

NEW YORK TRANSFORMER CO., INC.
ALPHA NEW JERSEY

(*Continued from page 16A*)

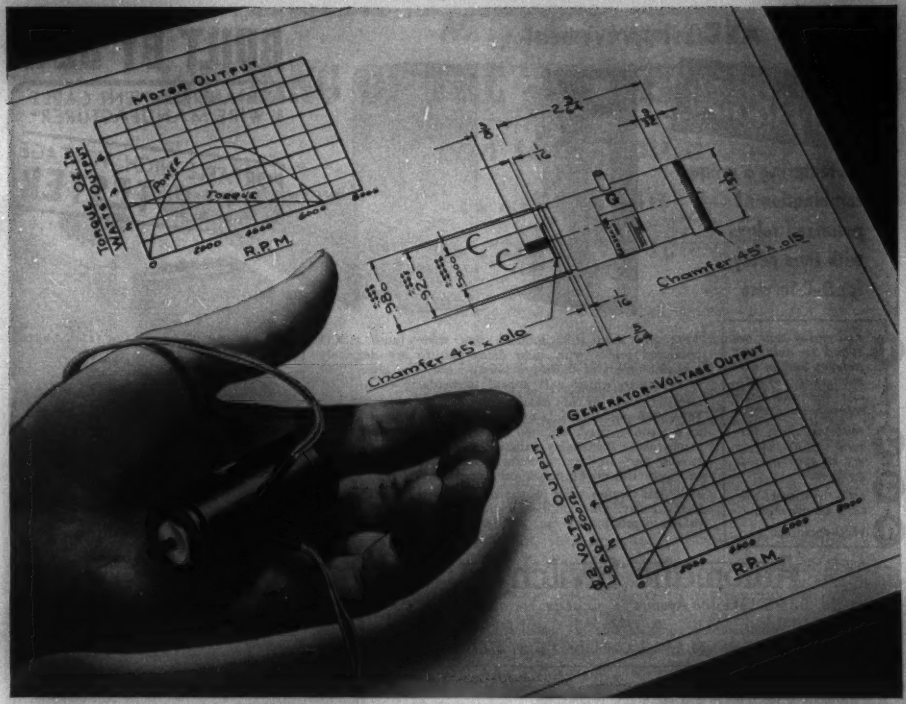
NEW PRODUCTS . . .

Pocket Thermometer. The Thermicator, a pocket-type thermometer introduced by the Tagliabue Instruments Division of the Weston Electrical Instrument Corporation, can be used either as an armored or a plain thermometer for temperatures between −30 degrees Fahrenheit and +120 degrees Fahrenheit. The Thermicator consists of an etched-stem glass thermometer, about the size of a fountain pen, enclosed in a spring pressure metal case. It can be suspended from a cord through its eye and immersed in a test fluid or medium like an armored thermometer. Large apertures in the case help assure better circulation of most light liquids or vapors around the bulb. For general temperature testing, where it is not exposed to the danger of breakage, the thermometer is removed from the case. Further details are available from the Tagliabue Instrument Division, Weston Electrical Instrument Corporation, Department 414, 614 Frelinghuysen Avenue, Newark 5, N. J.

Electric Control System. A new control system just announced by the Leeds and Northrup Company introduces rate action into an electrically actuated control. The significance of rate action is that it responds according to the speed with which the controlled variable changes, thus improving process output by reducing the length of time that an upset can force the controlled process off its set point. If furnace temperature, for example, begins to fall, rate action immediately opens the fuel valve. As the rate of temperature departure decreases, rate action's effect also decreases, to bring temperature smoothly back into line. This control, the *P.A.T. '50*, has proportional and reset control actions, and is applicable to the regulation of temperature, pH, chemical concentration, and gas analysis. The key element of the control system is a new control unit, which electrically links a micromax or speedomax recording instrument and a Leeds and Northrup electric valve drive mechanism. Additional information may be obtained from the Leeds and Northrup Company at 4934 Stenton Avenue, Philadelphia 44, Pa.

Gasketed Loom-Motor Starter. A new motor starter with a gasketed enclosure is available from the Westinghouse Electric Corporation. The starter is designed for starting and stopping polyphase induction motors, and also provides overload protection. The rotary-action, slam-proof handle mechanism operates an overcenter toggle mechanism that gives quick-make and quick-break contact action. A bimetallic disc-type thermal overload relay gives precisely calibrated motor protection. The starter is rated up to 600 volts, 7½-horsepower polyphase. De-ion arc-quenching chutes extinguish arcs within one-half cycle. Line terminals can be provided either at the top or bottom of the

(*Continued on page 40A*)



Remarkable new compactness in precision control

The extreme compactness of the new Type 1623 Motor-Driven Induction Generator has been achieved with no sacrifice of general performance characteristics. Like its "bigger brothers" in the Kollsman line, the Type 1623 combines, in a single frame, motors of high torque/inertia ratio with generators offering *linear voltage vs. speed* over a wide range.

Where size and weight are prime considerations, this 4.2-ounce unit will prove the solution to many precision control problems. Separate induction motors and generators are also available in the same diameter frame.

For further information on the 1623 and others in the complete Kollsman group of miniature special purpose AC motors—or if you require a unit to your own specifications—write: Kollsman Instrument Division, Square D Company, 80-08 45th Avenue, Elmhurst, N. Y.

Type 1623 Motor-Driven Induction Generator

Motor characteristics: Maximum torque at stall—smooth-running (will not "cog")—fast-reversing—operates from two-phase source, or from single-phase with phase-shifting condenser—available for 60 or 400 cycle operation.

Generator characteristics: Low residual voltage and voltage "spread"—constant frequency output—amplitude directly proportional to speed.

Unit characteristics: Both rotors mounted on same shaft, assuring positive alignment—stainless steel housing—hardened beryllium copper shaft—corrosion-resistant nickel steel laminations—high temperature insulation (up to 200° C. total temperature)—stainless steel precision ball bearings—weight: 4.2 ounces.

KOLLSMAN INSTRUMENT DIVISION

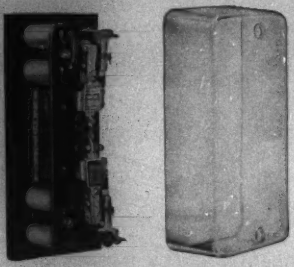
SQUARE D COMPANY

ELMHURST, NEW YORK GLENDALE, CALIFORNIA

Another ASCO Improvement

Relay 188S6

...featuring a unique combination of polarized relays with time delay for D-C Service



1. *each relay will respond to only one polarity and on momentary loss of voltage the energized relay does not move.*
2. *with sustained current off the relays are in open contact position.*
3. *relays are mechanically interlocked.*
4. *glass-enclosed.*

Thorough shop tests indicate that these latest ASCO polarized relays with time delay feature are definitely superior to any of those previously made. The glass cover is a feature which will appeal particularly to utilities. Delay Timing for this Relay is similar to that of Bulletin 1054-188S announced last spring—at any point from ½ to 3 seconds, predetermined and set at the factory. It's a magnetically held Relay without dashpot, motors or other moving parts in the time element. It is rated at 25 amperes and embodies utility power construction.

This unit typifies what can be done with the ASCO Time Delay Relay. Our engineers will be glad to discuss its values in relation to your requirements along these lines.

Automatic Switch Co.

385-E Lakeside Avenue Orange, New Jersey

We also manufacture a complete line of Solenoid Operated Valves for Automatic and Remote Control of Liquids and Gases.

Automatic Transfer Switches
Remote Control Switches
Contactors
Relays

WRITE FOR 80-PAGE MANUAL

Glutton for Punishment

They take punishment and like it—these one-piece, pure copper lugs which afford brute strength without excessive weight, silver-plated for top performance.

ILSCO

LO SOLDERLESS LUGS

Average **50% COOLER** *than "Ordinary" lugs (Underwriters' approved)*

Maximum wiring space where space-saving is paramount. 100% reusable, no loss.

Wire sizes from 14# to 600,000 cm.; easy to install with ordinary tools. Cost is much lower than coarse, bulkier cast lugs, although superior in performance.

5743 MARIEMONT AVE.

ILSCO COPPER TUBE & PRODUCTS, INC.

CINCINNATI 27, OHIO

BUILT BY BETA

FOR A PROMINENT CABLE & WIRE MANUFACTURER*

PORTABLE HIGH VOLTAGE CABLE TESTER

Model 219 control cabinet (high voltage tank not shown)

0—135 KV DC, High voltage (+) or (—) to ground

100 MA available at 135 KV, 230 MA available below 100 KV

Ripple less than 1%

Stabilized output voltage ± 1% against line voltage and load current changes.

Adjustable rate of rise of voltage: ½ to 10 KV per second

Many other control and metering features. Entire unit on swivel casters.

BETA High Voltage Cable Tester

This high voltage cable tester was built to provide safe, reliable and convenient source of very high voltage DC for power cable testing. Multiple range meters, protected on all ranges, allow for accurate insulation resistance characteristic measurements over a very wide range of resistance values.

*name given upon request

SPECIALIZING IN HIGH VOLTAGE EQUIPMENT

The Beta Electric Corporation specializes in the design and construction of high voltage equipment like the cable tester described above. These units are built for the client's application, to the client's specifications. Beta also builds a standard line of high voltage power supplies up to 30 KV, portable projection oscilloscopes, and kilovoltmeters. Beta stresses good design and construction, which make for efficient equipment, ease of operation, low maintenance costs, fast delivery, and low prices.

Field Engineer Service

Beta field engineers throughout the country are at your service to discuss high voltage applications and equipment.

PHONE OR WRITE TODAY!

BETA ELECTRIC CORP.

333 E. 103 St., New York 29, N. Y.

Maybe Stackpole's

WELDING OF THE "UNWELDABLE"

can save you money .... increase your product efficiency

Carbon contacts or brushes welded to metal arms, supports or holders.
Carbon welded to phosphor bronze or beryllium copper leaf spring.
Carbon welded to metal plate for friction drive.

A unique new process makes it just as practical to weld carbon to metal as it is to weld metal to metal in most cases. Thus, by joining this heretofore unwettable refractory material with metal supports, you gain all the advantages of carbon for contacts, small brushes, friction devices and other purposes—*while eliminating costly fixtures formerly necessary in bolting and clamping them in place.*

For example, this new method permits welding carbon contacts directly to metal arms. Carbon brushes can be soldered to phosphor bronze or beryllium copper leaf springs. Brush holders and shunts are eliminated. Equipment design is simplified. Carbon friction discs can be silver soldered directly to metal backing plates and so on.

Frankly we have not yet uncovered all the many jobs where this unique carbon-to-metal welding process can be applied. Minor limitations apply in some cases but these are seldom much of a factor. Stackpole engineers welcome the opportunity to cooperate on any problem where the method might pave the way to a worthwhile cost saving for your product, or an increase in its efficiency.

STACKPOLE CARBON COMPANY
ST. MARYS, PA.

STACKPOLE

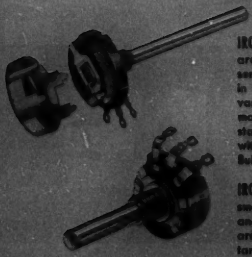
EVERYTHING IN CARBON BUT DIAMONDS

A complete line

for resistors too!

Unusual *combinations of characteristics* required in today's critical electronic circuits demand a complete range of resistor types. Specializing in resistors, IRC makes the widest line in the industry. This means ease of procurement—a single dependable source of supply for *all* your resistance needs. It also means unbiased recommendations—no substitution of units "just as good". IRC's complete line of products; complete research and testing facilities; complete network of licensees for emergency production—all add up to complete satisfaction for you.

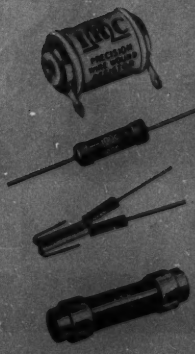
CONTROLS



IRC Type W Wire Wound Controls are designed for long, dependable service and balanced performance in every characteristic. These 2-watt variable wire wound units provide maximum adaptability to most rheostat and potentiometer applications within their power rating. Catalog Bulletin A-2.

IRC New Type Q Controls feature small 1⅛" size, rugged construction and superior performance. Increased arc of rotation permits same resistance ratios successful in larger IRC Controls. Catalog Bulletin A-4.

PRECISION RESISTORS



IRC Precision Wire Wounds offer a fine balance of accuracy and dependability for close-tolerance applications. Extensively used by leading instrument makers, they excel in every significant characteristic. Catalog Bulletin D-1.

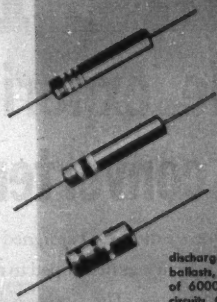
IRC Deposited Carbon PRECISTORS combine accuracy and economy for close-tolerance applications, where carbon compositions are unsuitable and wire-wound precisions too expensive. Catalog Bulletin B-4.

IRC Matched Pairs provide a dependable low-cost solution to close-tolerance requirements. Both Type BT and BW Resistors are available in matched pairs. Catalog Bulletin B-3.

IRC Sealed Precision Voltmeter Multipliers are suitable and dependable for use under the most severe humidity conditions. Each consists of several IRC Precisions mounted and interconnected, encased in a glazed ceramic tube. Catalog Bulletin D-2.

is essential

INSULATED COMPOSITION and WIRE WOUND RESISTORS

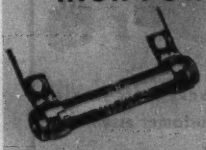


IRC Advanced Type BT Resistors meet and beat JAN-R-11 Specifications at ½, ½, 1 and 2 watts—combine extremely low operating temperature with excellent power dissipation. Catalog Bulletin B-1.

IRC Type BW Wire Wound Resistors are exceptionally stable, inexpensive units for low range requirements. Have excellent performance records in TV circuits, meters, analyzers, etc. Catalog Bulletin B-5.

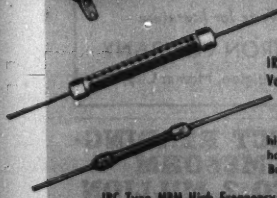
IRC Type BTAV High Voltage Resistors, developed for use as discharge resistors in fluorescent "Quick Start" ballasts, withstand momentary peak surge of 6000 volts. Also suited to TV bleeder circuits. Catalog Bulletin B-1.

HIGH FREQUENCY and HIGH POWER RESISTORS



IRC Type MP High Frequency Resistors afford stability with low inherent inductance and capacity in circuits involving steep wave fronts, high frequency measuring circuits and radar pulse equipment. Available in sizes from ¼ to 90 watts. Catalog Bulletin F-1.

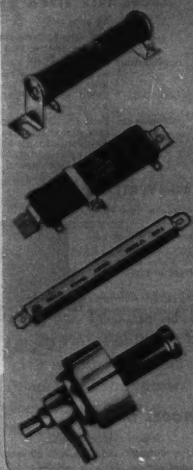
Type MV High Voltage Resistors utilize IRC's famous filament resistance coating in helical turns on a ceramic tube to provide a conducting path of long, effective length. Result: Exceptional stability even in very high resistance values. Catalog Bulletin G-1.



IRC Type MVX High Ohmic, High Voltage Resistors meet requirements for a small high range unit with axial leads. Engineered for high voltage applications, MVX has exceptional stability. Catalog Bulletin G-2.

IRC Type MPM High Frequency Resistors are miniature units suitable for high frequency receiver and similar applications. Stable resistors with low inherent inductance and capacity. Body only ⅜" long. Catalog Bulletin F-1.

POWER RESISTORS



IRC Fixed and Adjustable Power Wire Wounds give balanced performance in every characteristic—are available in a full range of sizes, types and terminals for exacting, heavy-duty applications. Catalog Bulletin C-2.

IRC Type FRW Flat Wire Wound Resistors fulfill requirements of high wattage dissipation in limited space—may be mounted vertically or horizontally, singly or in stacks. Catalog Bulletin C-1.

IRC Type MW Wire Wound Resistors offer low initial cost, lower mounting cost, flexibility in providing taps, and saving in space. Completely insulated against moisture. Catalog Bulletin B-2.

IRC Type LP Water-Cooled Resistors for TV, FM and Dielectric Heating Applications. Cooled internally by high velocity stream of water; adjustable to local water pressure and power dissipation up to 5 K.W.A.C. Catalog Bulletin F-2.

Wherever the Circuit Says -WW-

Power Resistors • Voltmeter Multipliers • Insulated Composition Resistors • Low Wattage Wire Wounds • Volume Controls • Voltage Dividers • Precision Wire Wounds • Deposited Carbon Precisions • Ultra-HF and High Voltage Resistors • Insulated Chokes

25 YEARS YOUNG IN 1950!

IRC

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PHILADELPHIA 8, PENNSYLVANIA
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INTERNATIONAL RESISTANCE CO.
411 N. BROAD ST., PHILADELPHIA 8, PA.

Please send me Technical Data Bulletins checked below:

☐ Bulletin A-2 (W)	☐ Bulletin B-4 (DC)	☐ Bulletin F-1 (MP)
☐ Bulletin A-4 (Q)	☐ Bulletin B-5 (BW)	☐ Bulletin F-1 (MPM)
☐ Bulletin B-1 (BT)	☐ Bulletin C-1 (FRW)	☐ Bulletin F-2 (LP)
☐ Bulletin B-1 (BTAV)	☐ Bulletin C-2 (PWW)	☐ Bulletin G-1 (MV)
☐ Bulletin B-2 (MW)	☐ Bulletin D-1 (WW)	☐ Bulletin G-2 (MVX)
☐ Bulletin B-3 (M/P)	☐ Bulletin D-2 (MF)	

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J. P. ARNDT & CO., ADV. AGENCY

ONLY C-D offers this wide experience in vibrator converter design

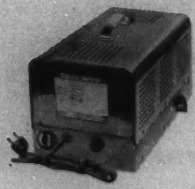
Here are three C-D designed Converters of widely divergent characteristics. Each was developed to meet the specific need of a Cornell-Dubilier customer. The Converter you need may be a far cry from any of the types shown here. But the same skill and experience used in developing these designs can be turned on your needs. Whether it is a fathometer, microwave apparatus, or office equipment, our engineers will be glad to discuss your problem.

MODEL 3212 VIBRATOR CONVERTER

input: 12 volts D-C.
output: 115 volts 60-cycle sine wave A-C with voltage and load regulation. Max. power: 175 volt amperes.
application: For vehicles with 12-volt systems (cabooses, busses, trucks, etc. carrying communications equipment, wire reproducing equipment, fluorescent or neon lights, that require 115 v., 60-cycle sine wave A-C for operation.
features: Exclusive C-D voltage regulating circuit permits only slight variations in output voltage for wide variations of input voltage or load. Two vibrators, with automatic switch-over from service vibrator to standby vibrator.

MODEL 3210 HEAVY-DUTY CONVERTER

input: 120 volts D-C nominal (normal range from 95 to 135 volts D-C).
output: 115 volts 60-cycle A-C Max. power: 375 volt amperes (continuous).
application: Railroad or marine service. For 2-way radio communication, radar, and other types of radio equipment
features: Exclusive C-D voltage regulating circuit. Automatic standby-vibrator switch-over. Electrical components have high safety factor for long life. Designed for vertical or horizontal mounting.



MODEL 110 RT 15

input: 115 volts D-C.
output: 115 volts A-C, 60-cycle.
application: For wire recorders.
features: Sine wave regulated; automatic starting; input line filtering.

Many stock models are shown in Catalog No. 410, available from: CORNELL-DUBILIER ELECTRIC CORPORATION, *2900 Columbia Ave., Indianapolis, Indiana. Other plants in South Plainfield, New Jersey; New Bedford, Brookline and Worcester, Massachusetts; Providence, Rhode Island; and subsidiary, The Radiart Corp., Cleveland, Ohio.*

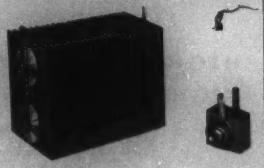
40TH ANNIVERSARY CORNELL-DUBILIER CONVERTERS 1910 1950

CORNELL-DUBILIER
VIBRATOR CONVERTERS
BEST BY FIELD TEST

SUBSIDIARY

A GREAT NAME IN CAPACITORS — A GREAT NAME IN CONVERTERS

SYNTRON
SELENIUM RECTIFIERS



—in stacks, or single cells for customer assembly.

Made by a new process to a uniform, high quality for continuous, heavy-duty service.

Write for literature

SYNTRON COMPANY
440 Lexington, Homer City, Pa.

DIRECT READING 1 MEGOHM UP TO 2 MILLION MEGOHMS

FREED NO. 1020

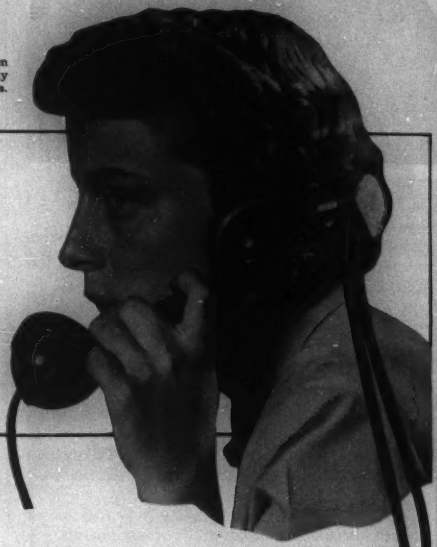
MEGOHMMETER

A self contained, AC operated megohmmeter with electronically regulated high voltage supplies. Measures the leakage resistance of insulating materials, condensers, cables, motor and windings.

Has a range of 1 megohm to 2,000,000 megohms in six overlapping ranges. Voltage applied to the unknown is 500 volts.

Send for the new Freed Catalog

FREED TRANSFORMER CO., INC.
Dept. DG 1718 WEIRFIELD ST.,
BROOKLYN (RIDGEWOOD) 27, NEW YORK



Testing for sound lost between telephone receiver and ear. Many subjects were used in these tests.

How to compensate for a curl . . . and add to your telephone value

Bell scientists know that the telephone is not used under ideal laboratory conditions. There is never a perfect seal between receiver and user's ear. A curl may get in the way, or the hand relax a trifle. And ears come in many shapes and sizes. So some sound escapes.

Now, sound costs money. To deliver more of it to your ear means bigger wires, more amplifiers. So Bell Laboratories engineers, intent on a thrifty telephone plant, must know how much sound reaches the ear, how much leaks away. They mounted a narrow "sampling tube" on an ordinary handset. The tube extended through the receiver cap into the ear canal. As sounds of many frequencies were sent through the receiver, the tube picked up a portion, and sent it through a condenser microphone to an amplifier. That sampling showed what the ear received.

As a result, Bell scientists can compensate in advance for sound losses—build receivers that give *enough* sound, yet with no waste. That makes telephone listening always easy and pleasant.

It's another example of the way Bell Telephone Laboratories work to keep your telephone service one of today's biggest bargains.

Automatic recorder plots sound pressures developed in the ear canal at different frequencies.

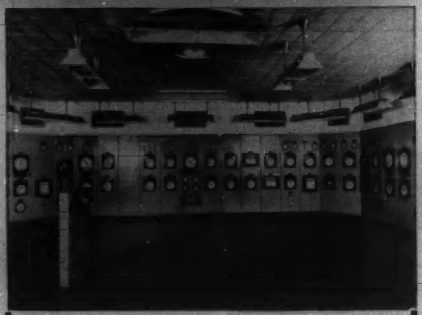
BELL TELEPHONE LABORATORIES

Working continually to keep your telephone service big in value and low in cost.

for electrical control applications

it's KIRK AND BLUM

FOR SHEET METAL ENCLOSURES



If you need an enclosure for one, two or three instruments, or hundreds of instruments, call on KIRK & BLUM for fast, accurate fabrication. The photo above shows a typical large installation. Almost 100 instruments and controls are visible in this installation in a major refinery.

KIRK & BLUM is equipped and experienced to fabricate one unit or hundreds, specializing in custom-built parts and assemblies of sheet steel, light plate, stainless, aluminum, monel and other alloys in gauges 3/8" and lighter.

For more detailed information, write now for your free copy of the NEW Kirk & Blum Electrical Enclosures booklet.

- Control Desks • Cubicles • Electrical Cabinets & Enclosures
- Power Distribution & Control Panels • Switch Gear Housings
- Boiler, Generator & Turbine Control Plants
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- Test Stands, Controls & Desks • Instrument Panels
- Outdoor Electrical Enclosures
- Transformer Tanks
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For prompt quotation, send prints to:

THE KIRK & BLUM MFG. CO.
2904 Spring Grove Ave. Cincinnati 25, Ohio

KIRK AND BLUM

IF YOU NEED

PORCELAIN INSULATORS LIKE THIS

WE KNOW HOW TO MAKE THEM!

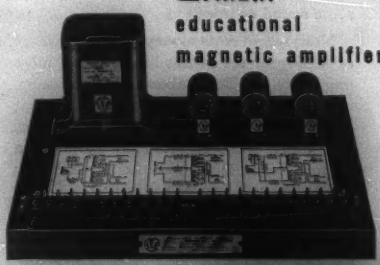
This insulator, with overall dimensions of 6 1/4 inches by 4 7/8 inches by 2 15/16 inches conceals under its smooth exterior, some difficult molding problems. As the photos show there is a 15/16 inch skirt. Above this the body carries a rectangular, tapered socket, 2 3/4 inch deep, four post holes and two through holes. Long experience in solving such intricate design problems enabled Universal engineers to successfully reproduce this piece to extremely close tolerances with each piece of uniform density. A Universal engineer will be glad to work with you.

THE UNIVERSAL CLAY PRODUCTS CO.
1560 EAST FIRST STREET U SANDUSKY, OHIO
TRADE MARK

VICKERS

educational

magnetic amplifier



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Experiments and Lecture Demonstrations

Designed by Vickers to help students obtain a wider knowledge of the characteristics and applications of high-performance self-saturating magnetic amplifiers.

- Permits study of all three basic single phase self-saturating circuits.
- Can actually be used in operating controls circuits.
- Gives d-c or a-c output, uses d-c or a-c control power.

INCLUDED WITH EACH UNIT—Magnetic Amplifier Laboratory Manuals and Magnetic Amplifier Design Handbooks.

Write for information and price.

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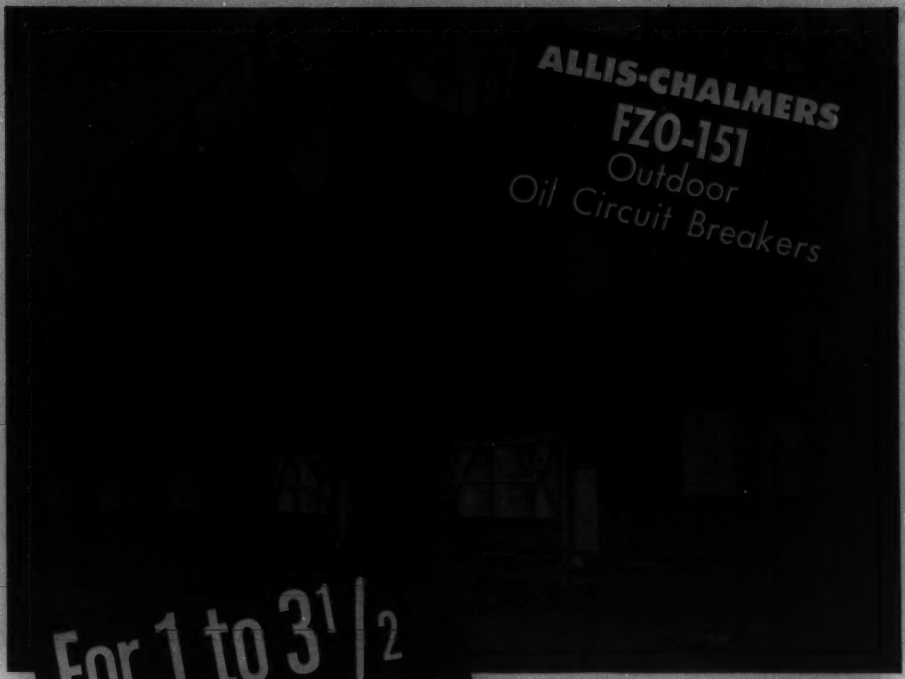


For 1 to 3½ Million KVA

- **MECHANICALLY TRIP-FREE PNEUMATIC OPERATOR** *assures positive tripping*
- **SINGLE-BREAK *RUPTOR* DEVICE** *(5 cycle interruption if required) for low arc energy release*
- **EVERY BREAKER** *factory assembled, tested, and shipped without dismantling.*

INSTANT, POSITIVE CONTACT OPENING under all conditions is *assured* with FZO-151 breakers. The reason is Allis-Chalmers mechanically trip-free pneumatic operator. In case of a fault, the operator is effectively uncoupled from contact mechanism by means of a positive mechanical linkage. Contacts open *independent of valve operation or cylinder back pressures* . . . there's nothing to hinder instant tripping.

Positive operation is further assured with simple, single-break *Ruptor* interrupting device that extinguishes arc without use of unnecessary moving parts that may bind or fail. Self-cleaning action of bayonet-type moving contacts prevents formation of high resistance oxides. Low inertia pole unit mechanism of straight line motion type gives high speed interruption with low arc energy release.

Complete factory test data accompanies every breaker. For details on Allis-Chalmers breakers for any utility need, contact your A-C sales office.

ALLIS-CHALMERS, 931A SO. 70 ST. MILWAUKEE, WIS.

STANDARD RATINGS
(8 cycle interruption)

Rated KV	Rated amp. 60 cycle	KVA Interrupting Capacity
69	600	1,000,000
69	1200	1,500,000
69	1200	2,500,000
69	2000	3,500,000

Ruptor is an Allis-Chalmers trademark

ALLIS-CHALMERS

GET NEW BULLETIN
71B7045 for ratings, dimensions and details of construction of type FZO-151 breakers.

A-3073

STANDARD RI-FI* METERS

14kc to 1000mc!

DEVELOPED BY STODDART FOR THE ARMED FORCES.

AVAILABLE COMMERCIALLY.

VHF!
15 MC
to
400 MC
NMA - 5

Commercial equivalent of TS-587/U. Sensitivity as two-terminal voltmeter, (95 ohms balanced) 2 microvolts 15-125 MC; 5 microvolts 88-400 MC. Field intensity measurements using calibrated dipole. Frequency range includes FM and TV Bands.

VLF!
14 KC
to
250 KC
NM - 10A

Commercial equivalent of AN/URM-6. A new achievement in sensitivity! Field intensity measurements, 1 microvolt-per-meter using rod; 10 microvolts-per-meter using shielded directive loop. As two-terminal voltmeter, 1 microvolt.

HF!
150 KC
to
25 MC
NM - 20A

Commercial equivalent of AN/PRM-1. Self-contained batteries. A.C. supply optional. Sensitivity as two-terminal voltmeter, 1 microvolt. Field intensity with ½ meter rod antenna, 2 microvolts-per-meter; rotatable loop supplied. Includes standard broadcast band, radio range, WWV, and communications frequencies.

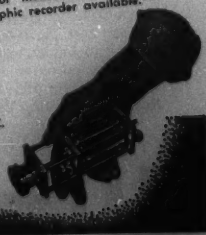
UHF!
375 MC
to
1000 MC
NM - 50A

Commercial equivalent of AN/URM-17. Sensitivity as two-terminal voltmeter, (50-ohm coaxial input) 10 microvolts. Field intensity measurements using calibrated dipole. Frequency range includes Citizens Band and UHF color TV Band.

Since 1944 Stoddart RI-FI* instruments have established the standard for superior quality and unexcelled performance. These instruments fully comply with test equipment requirements of such radio interference specifications as JAN-I-225, ASA C63.2, 16E4(SHIPS), AN-I-24a, AN-I-42, AN-I-27a, AN-I-40 and others. Many of these specifications were written or revised to the standards of performance demonstrated in Stoddart equipment.

The rugged and reliable instruments illustrated above serve equally well in field or laboratory. Individually calibrated for consistent results using internal standard of reference. Meter scales marked in microvolts and DB above one microvolt. Function selector enables measurement of sinusoidal or complex waveforms, giving average, peak or quasi-peak values. Accessories provide means for measuring either conducted or radiated r.f. voltages. Graphic recorder available.

*Radio Interference and Field Intensity.



Precision Attenuation for UHF!
Less than 1.2 VSWR to 3000 MC.
Turret Attenuator:
0, 10, 20, 30, 40, 50 DB.
Accuracy ± .5 DB.
Patents applied for.

STODDART AIRCRAFT RADIO CO.

[illegible] SANTA MONICA BLVD., HOLLYWOOD [illegible], CALIF.
Hillside 9294

HERE'S *Insulation* AT ITS BEST!

In the illustration above, Mica-Glas is being visually inspected and gauged for correct thickness. Bond content, dielectric strength, slippage and other characteristics are very carefully checked during manufacture and as a final inspection before shipment.

Mica-Glas, which is built up of hand-laid premium mica with glass cloth backing, has high dielectric strength, is resistant to heat and impervious to moisture.

With either long-life synthetic resin or silicone bonding, it is available in sheets, rolls and tape, in standard thicknesses and widths. In addition, Mica-Glas can be obtained in .0035" thickness—ideal where a minimum of space is available, and for turns of small radius.

To insure uniform insulation value, National impregnates the glass cloth in a National-designed coating tower which meters and cures the varnish with uniform accuracy. Mica splittings are applied under close control and are bonded tenaciously to the glass cloth. When you use Mica-Glas you *know* your electric windings are using the best.

Use Mica-Glas, and other National insulation, for *known high value*. Some of the world's largest manufacturers of electrical equipment standardize on it.

NATIONAL MICA-GLAS INSULATION

TRADE MARK

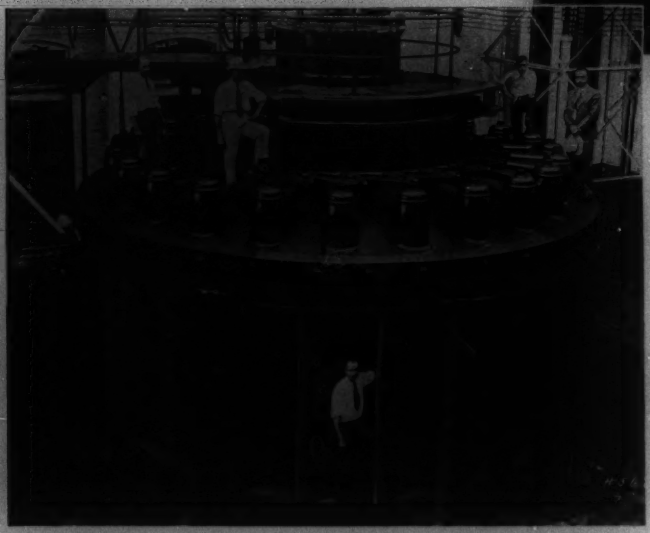
NATIONAL ELECTRIC COIL COMPANY

COLUMBUS 16, OHIO, U. S. A.

ELECTRICAL ENGINEERS MAKERS OF ELECTRICAL COILS AND INSULATION — DESIGNING AND REPAIRING OF ROTATING ELECTRICAL MACHINES

FROM THE SMALLEST TO THE LARGEST

500 Horsepower—
83-foot Head



57,000 Horsepower—
81-foot Head

Hydraulic turbines in all sizes, using either Francis or propeller type runners, have been built at Newport News for use throughout the United States and many parts of the world.

Shown above are: one using a 16½-inch runner in a cast iron spiral casing and another using a 238½-inch runner in a riveted steel plate spiral casing.

Newport News built hydraulic turbines, aggregating a rated output of more than 5,900,000 horsepower, have been furnished for such plants as Grand Coulee, Hoover, Norris, Wilson, Dnieprostroy, and many others. Hydraulic turbine work now in progress at Newport News is in excess of 1,000,000 horsepower. Inquiries are invited.

"Water Power Equipment" booklet sent upon request.

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SHIPBUILDING AND DRY DOCK CO.
NEWPORT NEWS VIRGINIA

Now Available!

MOLYBDENUM PERMALLOY POWDER CORES*

HIGH Q TOROIDS for use in Loading Coils, Filters, Broadband Carrier Systems and Networks—for frequencies up to 200 KC

COMPLETE LINE OF CORES TO MEET YOUR NEEDS

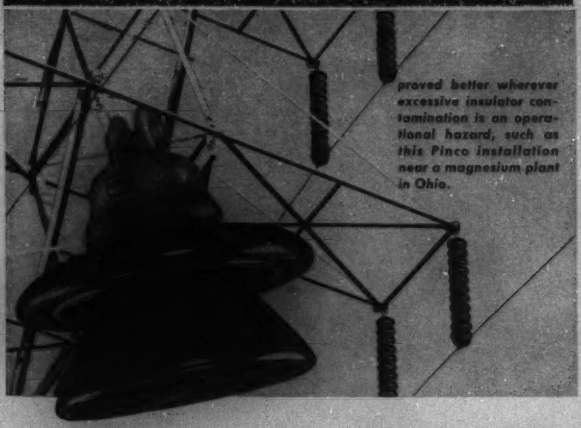
- ★ **Furnished in four standard permeabilities—125, 60, 26 and 14.**
- ★ **Available in a wide range of sizes to obtain nominal inductances as high as 281 mh/1000 turns.**
- ★ **These toroidal cores are given various types of enamel and varnish finishes, some of which permit winding with heavy Formex insulated wire without supplementary insulation over the core.**

For high Q in a small volume, characterized by low eddy current and hysteresis losses, ARNOLD Moly Permalloy Powder Toroidal Cores are commercially available to meet high standards of physical and electrical requirements. They provide constant permeability over a wide range of flux density. The 125 Mu cores are recommended for use up to 15 kc, 60 Mu at 10 to 50 kc, 26 Mu at 30 to 75 kc, and 14 Mu at 50 to 200 kc. Many of these cores may be furnished stabilized to provide constant permeability (±0.1%) over a specific temperature range.

*Manufactured under licensing arrangements with Western Electric Company.

WAD 2930

RIGHT for the JOB... RIGHT ON THE JOB!



proved better wherever excessive insulator contamination is an operational hazard, such as this Pinco installation near a magnesium plant in Ohio.

Competitive Tests...Service Records Prove the Superiority of PINCO L1612 "Universal" Insulators

In competitive "fog operation" tests conducted by a Western power company, Pinco L1612 Insulators rated . . .

FIRST on "fog arc over."

FIRST on sustained voltage "in fog" . . . NO arc over.

FIRST on sustained voltage "in direct spray" . . . NO arc over.

FIRST on both self-cleaning and manual cleaning characteristics.

SECOND on "sluice arc over."

EXCELLENT on radio interference characteristics.

We're proud that Pinco Insulators were so conclusively proved "right" by such laboratory tests. But we're even more proud to know that in actual operation under "fog" conditions, thousands of Pinco L1612's have been meeting their job requirements 100% on installations *made eighteen years ago!* Such a record of trouble-free service proves that they're "right" where it counts . . . "right on the job!" So when you have a tough job for insulators calling for L1612 characteristics . . . put up Pinco *to be sure!*

See Page 70, Pinco Catalog No. 49 for complete electrical and mechanical characteristics.

The Porcelain Insulator Corporation

763 Main Street, Lima, N. Y.

Sales Agents: JOSLYN MFG. & SUPPLY CO.
Offices in Principal Cities

PINCO INSULATORS

Suspension Insulators . . . Switch and Bus Insulators . . . Distribution Clamps . . . Distribution Pin Types and Guy Strains . . . Transmission Line Fittings . . . Tree Insulators . . . Transformer and Circuit Breaker Bushings . . . One Piece and Multi-part High Voltage Pin Types . . . Suspension and Strain Clamps . . . Indoor Bus Support Porcelain . . . Lightning Arrester Porcelain.

• 1920 Thirty Years Service to the Electrical Industry 1950 •

(*Continued from page 26A*)

enclosure. Further details can be obtained from the Westinghouse Electric Corporation, Box 2099, Pittsburgh 30, Pa

One-Piece Bronze Distribution Connectors. Anderson Brass Works, Inc., Post Office Drawer 2151, Birmingham 1, Ala., has introduced a series of one-piece distribution connectors, catalog series *K-90* and *K-900*, for making taps, splices, and dead ends. The *K-90* and *K-900* series each include four sizes of connectors to accommodate connections of copper conductor combinations from number 8 to 500,000 circular mils. The mechanical features and high strength properties incorporated in the series transmit and convert higher clamping torque values into high pressure contacts on conductors completely enclosed in clamping members. These design and alloy characteristics provide for flexing of clamping members free from permanent set to retain high-pressure contacts for sealing out high-resistance oxide formation on contact areas, and for equal distribution of current in conductor strands during vibration or expansion and contraction resulting from temperature changes. Any further details may be obtained from the company.

Intermodulation Meter. Laboratory standard model *31*, a self-contained intermodulation meter manufactured by the Measurements Corporation of Boonton, N. J., is a test signal generator and an analyzer. A built-in supply provides power for both units. The generator section produces two sinusoidal voltages, one of low frequency and the other of high frequency, which are mixed in a 4-to-1 voltage ratio and applied to the apparatus under test. The signal from the equipment being tested is then received by the analyzer section of the model *31* to be filtered, amplified, demodulated, and metered. The meter is direct-reading in percentage of intermodulation and input volts. This instrument can be used for evaluating the performance of audio systems, for adjusting and maintaining audio and frequency-modulation receivers and transmitters, for checking linearity of film and disc recordings and reproductions, and for quality control of all audio components and equipment. Any other details may be obtained from the company.

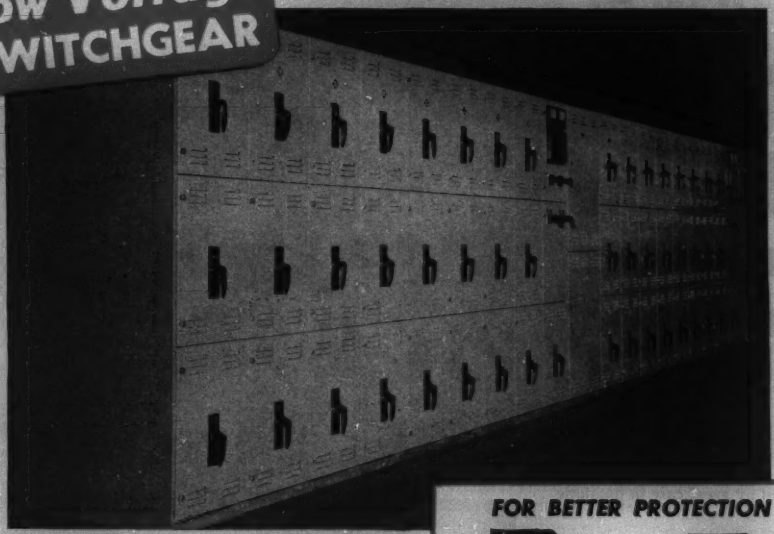
Hook Stick Switch. A 1,200-ampere hook stick switch for voltages from 7.5 through 23 kv has been developed by the A. B. Chance Company. Special features of the switch are the method of applying contact pressure and the lever pryout action of the pull-ring mechanism. A split-contact tongue permits pressure of the blade to be centered directly over the contact area. Blade pressure is applied by a heavy coil spring outside the contact point. A lever action has been built into the pryout mechanism enabling the operator to open the switch easily under all conditions. Double hooks backed by

(*Continued on page 52A*)

Engineered Protection

INSIDE AND OUT!

ALLIS-CHALMERS
Low Voltage SWITCHGEAR



ALLIS-CHALMERS Low Voltage Metal Enclosed Switchgear provides maximum protection to electrical circuits and equipment: first, by the performance of the circuit breaker; second, by the extra switchgear features.

Heart of your switchgear is the circuit breaker. That's why you want best performance from it. Type G-25 and G-50 circuit breakers give balanced operation, quick arc interruption and wide current carrying range. They are insensitive to shock and vibration. Arcing contacts fitted with silver-tungsten tips resist arc erosion and mechanical wear. Breakers of same rating are interchangeable.

Proper coordination of complete switchgear design provides ease of operation and maintenance. A self-aligning pantograph arrangement for circuit breaker withdrawal holds breaker rigidly at any position. You can test the breaker in the disconnect position inside the switchgear unit. Safety features equal or exceed NEMA and ASA standards. Entire structure is grounded to insure safety of personnel.

To make the switchgear rigid the structure is jig welded with lap joints of all steel channels and angles. Surfaces are treated to resist corrosion, then given a lasting paint finish. Standardized designs are rated up to 600 volts ac and 250 volts dc.

For more information see your local A-C sales office or write direct for bulletin 18B6376A. A-3198

FOR BETTER PROTECTION

Low Voltage Air Breakers
Used on systems up to 600 volts ac or 250 volts dc. Manual or electrical operation. For protection of lighting loads, transformers or motors.

Pantograph Drawout
A simple and effective way of withdrawing Low Voltage breakers. Screw mechanism actuated by crank handle opens and closes pantograph.

Single Bus Design
Single main bus risers to circuit breakers in 2 or 3 high units, eliminates bus transition units. Gives more room for incoming cables.

Wall Mounted Breakers
Spot your protection where it is needed. Steel enclosure for breaker has dead front construction; dust-tight and weather proof.

ALLIS-CHALMERS, 931A SO. 70 ST.
MILWAUKEE, WIS.

ALLIS-CHALMERS

Proper Handling

PROTECTS THE LONG LIFE INHERENT IN KERITE CABLE

THE EXCELLENCE that is designed and built into Kerite Cable is protected by great care in handling at all times.

Unusual precaution and care in all stages of manufacture, constant checking and rechecking, sound methods of preparation for shipment . . . all make certain that Kerite's quality is preserved for the ultimate user.

Fine engineering, conscientious workmanship, and proper handling combine to protect the long life that is inherent in all Kerite Insulated Cable.

Kerite engineers will be glad to help you with your cable problems, whatever they may be.

THE KERITE COMPANY,
30 Church Street, New York 7, N. Y.
Offices also at 122 S. Michigan Avenue, Chicago; 582 Market Street, San Francisco; 714 W. Olympic Blvd., Los Angeles.

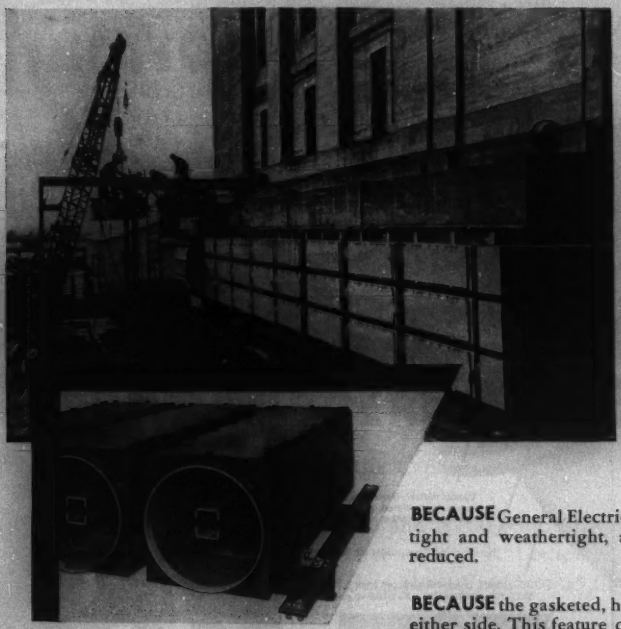
KERITE CABLE

Kerite Insulation—Your Cable's Best Life Insurance

11 of the 16 largest turbine-generators*

use

GENERAL ELECTRIC ISOLATED PHASE BUS RUNS



RATINGS
15 and 23 kv
1200 to 7000 amperes

Your G-E Sales Representative has complete information about isolated-phase bus runs. Ask him for a copy of GEA-5460, a 28-page publication that will aid you in planning your bus runs, or write to *Apparatus Department, General Electric Company, Schenectady 5, New York.*

BECAUSE General Electric isolated-phase bus runs are dust-tight and weathertight, and maintenance costs are thus reduced.

BECAUSE the gasketed, hinged covers can be opened from either side. This feature cuts inspection time and costs by allowing access to the interior of the run from the most convenient position. Cover lugs release the cover without removal of bolts. The cover is swung open on either one of two sets of hinges.

BECAUSE you receive G-E isolated-phase bus runs completely assembled as a three-phase package, including running ground bus. They are installed in a short time at lower predictable costs.

BECAUSE you have one source of responsibility when you order from General Electric—complete co-ordination between planning, engineering, manufacturing, and service facilities to give maximum savings efficiency to the customer.

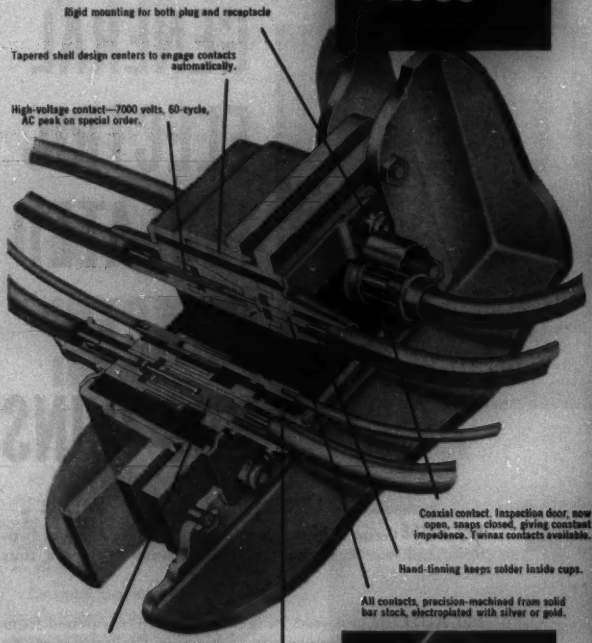
*Installed and planned, rated 6000 amperes and over.

GENERAL ELECTRIC

Here's why those in the know

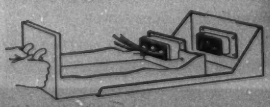
—demand

CANNON PLUGS


Rigid mounting for both plug and receptacle
Tapered shell design centers to engage contacts automatically.
High-voltage contact—7000 volts, 60-cycle, AC peak on special order.
Coaxial contact. Inspection door, now open, snaps closed, giving constant impedance. Twinax contacts available.
Hand-tinning keeps solder inside cups.
All contacts, precision-machined from solid bar stock, electroplated with silver or gold.
Socket contacts are full-floating—turn through 360°. Quick, self-centering—eases inspection.
Highly legible contact numbers on insert faces.
Inserts of latest approved high dielectric materials.

Insert arrangements are available with 2 to 45 contacts ranging from 15 amp to 200 amp capacity. Continuous shielding available in Coaxial and Twinax. Metal finish on shells for shielding and bonding: tin plating on aluminum. Other finishes available on special request.

Your requirements are responsible for the 8 to 10 design advantages found in each type of Cannon Plug. That's why engineers know the specification is right when it calls for CANNON. The DP Connector Series is just one of many Cannon types —world's most complete line. Request bulletins by required type or describe connector service you need.



Type DPD Connectors are permanent installations in rack and panel equipment . . . mate automatically . . . have weight and space-saving advantages over other connector types.

CANNON ELECTRIC

Since 1915

LOS ANGELES 31, CALIFORNIA

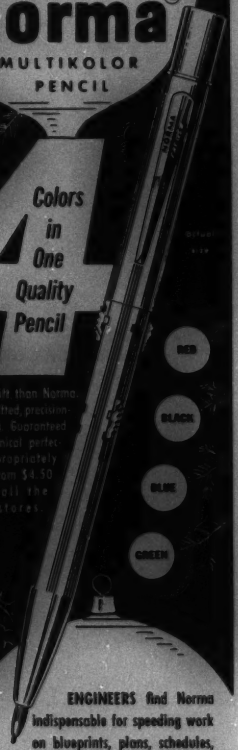
THE VERSATILE PENCIL OF TOMORROW

The Present with a Colorful Future

norma®

MULTIKOLOR PENCIL

4 Colors in One Quality Pencil



No finer gift than Norma. Jewelry-crafted, precision-engineered. Guaranteed for mechanical perfection. Appropriately boxed. From $4.50 up—at all the better stores.

ENGINEERS find Norma indispensable for speeding work on blueprints, plans, schedules, etc. . . . Yellow may be substituted for any color on request. Write for new booklet giving many other uses for 4-color Norma Pencils; no obligation.

NORMA PENCIL CORP., Norma Building EE3
137 West 14th Street, New York 11, N. Y.

Please send me, without charge, your new color booklet showing how Norma Pencils help to speed special daily tasks.

Name.....

Address.....

City.....Zone.....State.....

TINY • DEPENDABLE • SPACE-SAVING

Cera-mite Capacitors

ACTUAL SIZE

THE *First* COMPLETE DISC CERAMIC LINE

Sprague-Herlec Cera-mite Capacitors are a *"must"* for modern television circuits.

Now available in NP0 and N750 temperature-compensating bodies and in two different high-K bodies, Cera-mites meet most application needs in the 10 mmf to 15,000 mmf capacitance range.

These miniature capacitors offer set designers maximum space economy, ease of mounting, and improved very-high-frequency performance.

The flat disc with uni-directional lead construction has minimum self-inductance and a higher self-resonant frequency than a tubular design; hence improved v-f bypass efficiency.

Sprague-Herlec Engineering Bulletin 601B gives the complete list of standard ratings as well as performance specifications. Write for your copy today!

*Trademark

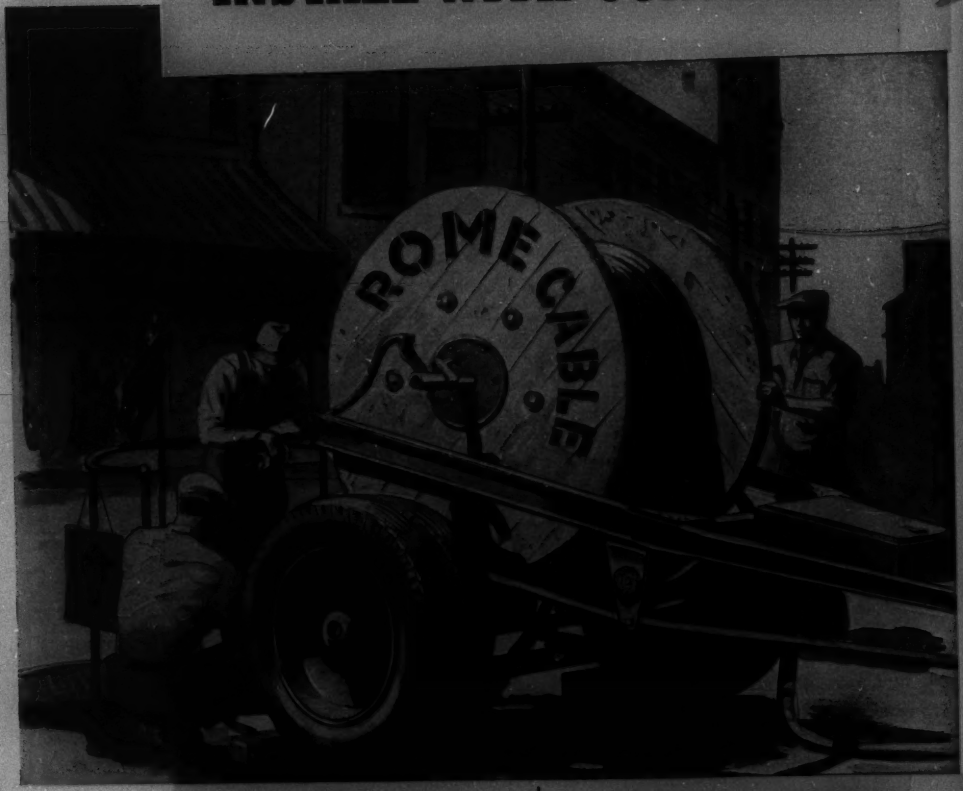
SPRAGUE

SPRAGUE ELECTRIC COMPANY
North Adams, Massachusetts

PIONEERS IN
ELECTRIC AND ELECTRONIC DEVELOPMENT

THE HERLEC CORPORATION • Milwaukee 3, Wisconsin

FOR CABLE YOU CAN INSTALL WITH CONFIDENCE



Multi Conductor RoZone-RoPrene* Power Cable—5000 Volts

RoZone-RoPrene Station Control Cable—600 Volts

Single Conductor RoZone-RoPrene Power Cable—8000 Volts Ungrounded Neutral

RoZone-RoPrene Series Street Lighting Cable—2001 to 8000 Volts

SPECIFY RoZone*

The Superior Ozone Resistant Insulation

In high voltage applications where long service life under severe conditions is imperative, Rome RoZone insulation is outstanding. A high quality oil-base compound, its resistance to corona and ozone cutting is exceptional. This, combined with unexcelled resistance to moisture, as well as aging, heat and sunlight, makes Rome RoZone insulated cable completely trouble-free . . . a cable you can install with complete confidence.

Rome RoZone is the result of years of successful operating experience, modern chemical knowledge, materials and up-to-date facilities. Its remarkable stability in water recommends it as the insulation for cables to be buried direct in earth, in wet locations, even for d-c operation where electro-osmosis presents a difficult problem. High dielectric and impulse strength, excellent aging characteristics, plus immunity to corona and ozone cutting especially qualify Rome RoZone as a superior high voltage insulation.

The dependability and high quality of Rome RoZone have made it *first* choice for many applications.

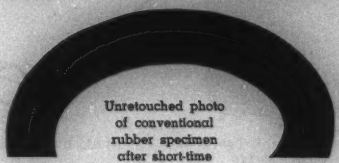
Rome RoZone is the Ideal Insulation for:

High Voltage Power Cables
Series Street Lighting Cables
Station Control and Signal Cables
General Purpose Wiring Where Dependable Quality is Paramount

It Costs Less To Buy the Best

*T. M. Reg.

Unretouched photo of RoZone specimen after long-time ozone test



Unretouched photo of conventional rubber specimen after short-time ozone test

Check These Rome RoZone Premium Quality Features:

- High Dielectric and Impulse Strength
- Excellent Resistance to Corona and Ozone Cutting
- Remarkable Electrical Stability in Water
- Inherent Resistance to Heat, Aging and Sunlight

JUST OFF THE PRESS!

The New Rome Power and Control Cable Catalog

This new sixty-page catalog will be an important addition to your book shelf! Complete in every detail, it includes descriptions, specifications, test data and suggested applications for all Rome Power and Control Cables. You'll find it invaluable for specifying. Mail coupon below today!

ROME CABLE CORPORATION, Dept. EE-12, Rome, N. Y.

Please send copy of new Rome Power and Control Cable Catalog.

Name .....

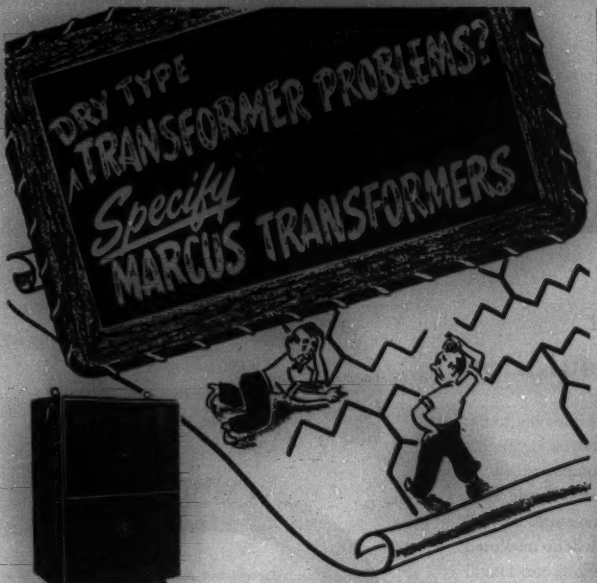
Company .....

Address .....

City ..... Zone ..... State .....

ROME CABLE Corporation
ROME • NEW YORK

ROME CABLE ROME, N.Y.



100 KVA, Type F Transformer 2400/120/240

450 KVA, Type F Unit Substation, 4160 V. Delta, 60 Cycles, 3 Ø— 120/208Y, 4 wire.

ONE OF THE WORLD'S LARGEST MANUFACTURERS OF DRY TYPE TRANSFORMERS EXCLUSIVELY

1 to 2,000 KVA up to 15,000 Volts to meet Individual Requirements

- DISTRIBUTION
- GENERAL PURPOSE
- UNIT SUBSTATION
- PHASE CHANGING
- ELECTRIC FURNACE
- RECTIFIER
- WELDING
- MOTOR STARTING
- SPECIAL

Made by a pioneer in the dry type, air-cooled transformer field. Eliminate need for liquid filled units. No hazardous, inflammable oil or toxic liquid to fuss with. Maintenance of oil level, foreign matter, sludge accumulation, and subsequent filtering are relegated to the "horse and buggy days".

MARCUS DRY TYPE, AIR-COOLED TRANSFORMERS

ARE SAFE — No explosion or fire hazards. No fire proof vaults. Class B and C heat proof insulations.

ARE ECONOMICAL — Lower cost installation and operation, negligible maintenance.

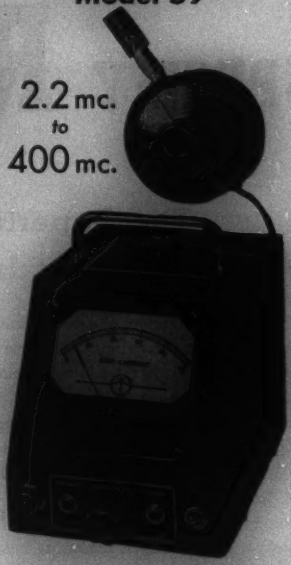
For the transformer that's second to none, specify MARCUS.

MARCUS
TRANSFORMER CO.
INC.
32 MONTGOMERY STREET
HILLSIDE 5, NEW JERSEY

PIONEERS IN THE FIELD OF AIR-COOLED TRANSFORMERS

MEASUREMENTS CORPORATION
Model 59

2.2 mc. to 400 mc.



MEGACYCLE METER

Radio's newest, multi-purpose instrument consisting of a grid-dip oscillator connected to its power supply by a flexible cord.

Check these applications:

- For determining the resonant frequency of tuned circuits, antennas, transmission lines, by-pass condensers, chokes, coils.
- For measuring capacitance, inductance, Q, mutual inductance.
- For preliminary tracking and alignment of receivers.
- As an auxiliary signal generator; modulated or unmodulated.
- For antenna tuning and transmitter neutralizing, power off.
- For locating parasitic circuits and spurious resonances.
- As a low sensitivity receiver for signal tracing.

TELEVISION INTERFERENCE

The Model 59 will enable you to make efficient traps and filters for the elimination of most TV interference.

Write for Special Data Sheet, 59TVI

SPECIFICATIONS:

Power Unit: 5½" wide, 6½" high; 7½" deep. Oscillator Unit: 3¾" diameter; 2" deep.

FREQUENCY:
2.2 mc. to 400 mc., seven plug-in coils.

MODULATION:
CW or 120 cycles; or external.

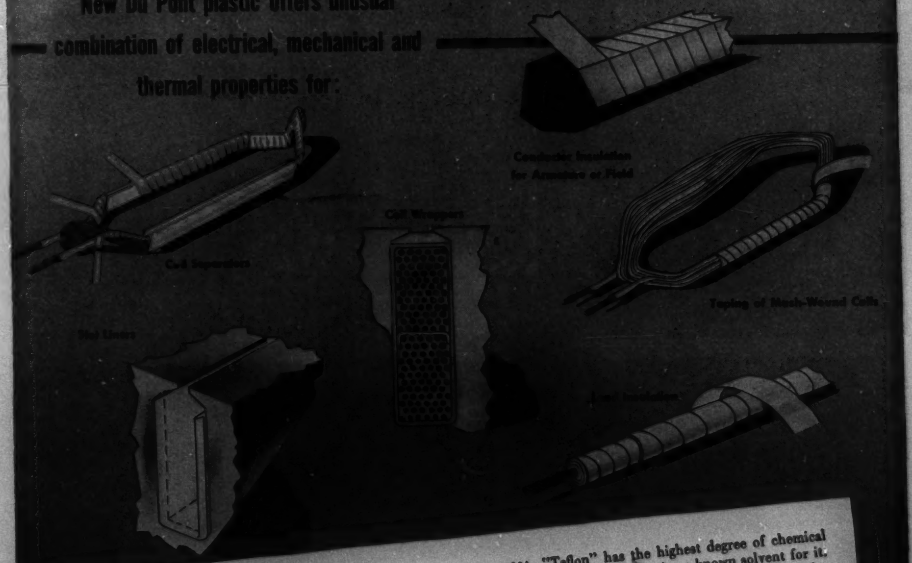
POWER SUPPLY:
110-120 volts, 50-60 cycles; 20 watts.

MEASUREMENTS CORPORATION
BOONTON NEW JERSEY

Insulate all these parts with tough TEFLON tape

REG. U. S. PAT. OFF.

New Du Pont plastic offers unusual combination of electrical, mechanical and thermal properties for:



Look at these properties!

MECHANICAL. "Teflon" tetrafluoroethylene resin is extremely tough—withstands considerable abuse in assembly and in use. Doesn't deteriorate with time. In applying, it's easy to handle, smooth, conforms well to corners and odd shapes—is adaptable to automatic operations.

ELECTRICAL. Its electrical properties are excellent over wide ranges of temperatures and frequencies. Its power factor is less than 0.05% over the entire spectrum measured to date. Short-time dielectric strengths are high. "Teflon" has good arc-resistance, and doesn't carbonize under an arc discharge. It has zero water-absorption.

THERMAL. "Teflon" is capable of continuous service at 250°C. (482°F.) without deterioration, exceeding the requirements of even Class H materials. In laboratory tests, molded bars kept at 250°C. for one month show only a 1% loss in tensile strength. "Teflon" also maintains good properties down to as low as −196°C. (−320°F.). Thus, an insulation of "Teflon" on a motor would not crack when motor is started in arctic temperatures.

CHEMICAL. "Teflon" has the highest degree of chemical inertness of any plastic. There is no known solvent for it. Thus, it is ideal for motors and generators operating under corrosive atmospheric conditions. "Teflon" is unaffected by outdoor weathering, as well. Samples exposed in Florida for over five years are completely unchanged.

E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Department, Sales Offices: 350 Fifth Avenue, New York 1, N. Y.; 7 S. Dearborn St., Chicago 3, Ill.; 845 E. 60th St., Los Angeles, Calif.

DU PONT
REG. U. S. PAT. OFF.
PLASTICS
Better Things for Better Living
. . . through Chemistry

Write today for free booklet on "Teflon" Tape

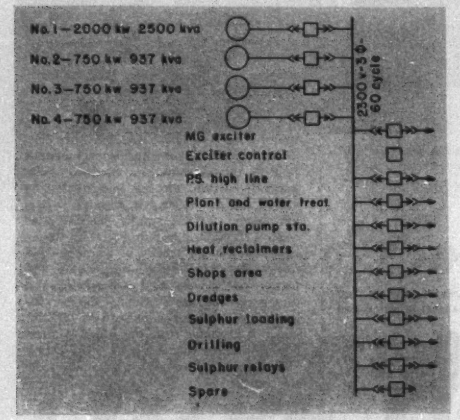
FREEPORT SULPHUR EXPANDS

This inadequate, open-type switchgear was replaced by the new G-E Metal-clad equipment shown below. Freeport Sulphur officials recognized that the old switchgear had outgrown its usefulness.

Here's the new General Electric 5-kv Metal-clad switchgear installed at Freeport Sulphur. Magne-blast power circuit breakers have plenty of "IC" (Interrupting Capacity) to handle all short circuits that may occur on Freeport's expanded distribution system. This assures continuous power for vital production.

AND MODERNIZES WITH

METAL CLAD SWITCHGEAR



This one-line diagram shows power distribution at Freeport Sulphur as planned by Sargent and Lundy, consulting engineers of Chicago. General Electric Metal-clad switchgear handles the 2300-volt power from the generators through power circuit breakers of 100,000-kva interrupting rating.

The Freeport installation is a complete General Electric project—one source of responsibility plus the very best in co-ordinated planning, engineering, manufacturing, and service facilities to give maximum savings and efficiency to the customer.

Be sure to see the "More Power to America" full-color sound slide-film "Modern Industrial Power Distribution." Ask your G-E sales representative to arrange a showing for your organization.

WHEN Freeport Sulphur expanded their production facilities they put in a new turbine to take care of the increased load.

At the same time they replaced all their old equipment with General Electric switchgear.

When you order G-E switchgear you get all the equipment and service from one reliable source. And with everything pre-assembled at the factory it takes very little time to get the switchgear in place and operating.

MODERN INDUSTRIAL power distribution systems using G-E switchgear are applicable to any industrial plant or commercial building where you want. . . .

- Proper voltage for top performance of equipment
- An extremely flexible setup to take care of expanding or changing loads
- Adequate short-circuit protection
- Protection for personnel
- Low installation and maintenance costs

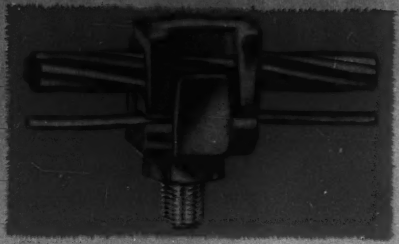
INVESTIGATE TODAY the many advantages of using General Electric switchgear to get the same benefits gained by Freeport Sulphur. Contact your G-E sales representative for further information—or write for the helpful bulletins listed below. *Apparatus Department, General Electric Company, Schenectady 5, New York.*

GEA-3083 Metal-clad Switchgear
GEA-4966 Low-voltage Metal-enclosed Switchgear
GEA-3592 Load-center Unit Substations
GEA-3758 Load-center Power Distribution

GENERAL ELECTRIC

NEW ONE PIECE K-90 AND K-900 SERIES DISTRIBUTION CONNECTORS

FOR ECONOMICAL FAST TROUBLE FREE CONNECTIONS K-90 AND K-900 SERIES OFFERS:



ECONOMICAL CONNECTIONS

- Low unit connector cost
- Lower installation cost
- Four sizes for connections up to 500 MCM
- Reduces inventory investment

COORDINATED ELECTRICAL MECHANICAL *and* METALLURGICAL DESIGN

Ability of design to consistently withstand mercurous nitrate test ABW Specification 124-1* which insures against seasonal cracking and stress corrosion cracking failures.

Mechanical design and alloy properties incorporating tensile and flexing characteristics consistent with maintaining high pressure contacts on varied conductor size during vibration, expansion and contraction from temperature changes. These features eliminate the necessity of a locking device.

Unique design and combination of special high strength alloys permitting higher clamping torque values being transmitted and converted into high contact pressures.

High pressure contacts which seal out formation of high resistance oxides on contact areas and lend to an equal distribution of current in conductor strands.

One piece design with interlocking clamping members which completely enclose conductors.

Perfected design permitting rapid easy method of making positive trouble free taps, splices and dead ends.

Design eliminates parts to assemble when installing. Eliminates starting threaded members. Eliminates crossed or stripped threads resulting from collapsed groove in threaded part when normal tightening torques are applied. Eliminates loosening of a properly installed connection due to vibration, temperature changes and cold flow of metals.

* Identical to ASTM B-154-45 Mercurous Nitrate Specification except ABW-124-1 specifies stressed components which is a more severe test.

Consult one of our nearest 19 representatives or contact our main office.

Write today for Bulletin K-150 on K-90 and K-900 Distribution Connectors.

ANDERSON BRASS WORKS, INC.

POST OFFICE DRAWER 2151

BIRMINGHAM, 1, ALABAMA

[redacted]

(*Continued from page 40A*)

a heavy spring out of the current path hold the switch closed against heavy current surges. The switch is available in single-throw or tandem transfer design for vertical or underhung mounting. Any further details may be obtained from the A. B. Chance Company, Centralia, Mo., upon written request.

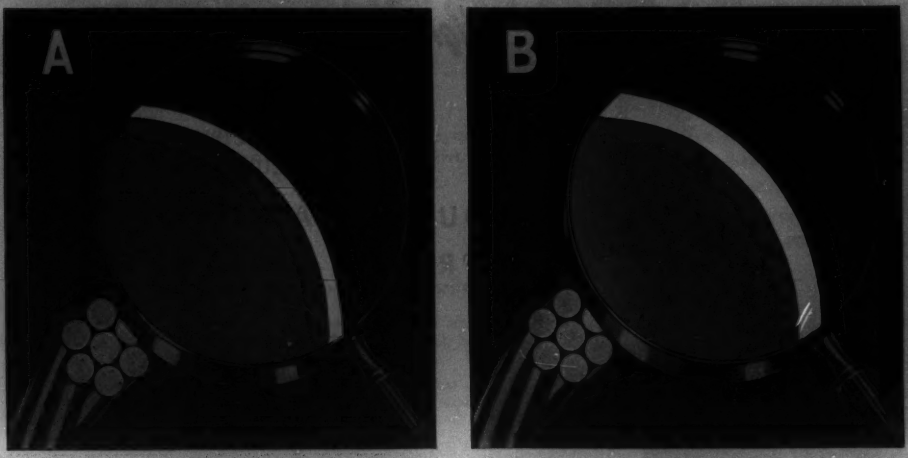
Liquid Rheostat. The type 257 Allis-Chalmers liquid rheostat is designed to give a constant rate of motor speed change over the entire travel of the movable electrode—motor speed changes the same amount for equal electrode travel anywhere within range of the rheostat. Motor speed is varied by raising or lowering the movable electrode and the electrolyte level within the cells. This changes resistance by varying both the distance between electrodes and the current-carrying area of the electrolyte. Since the electrolyte functions as the resistance, its level must be controlled. Liquid level is maintained just above the movable electrode by a weir outlet which is mechanically tied to the adjusting mechanism. Heat generated within the cell is dissipated by circulating the electrolyte through a heat exchanger. The rheostat's stepless speed control is desirable for variable torque load such as induced- and forced-draft fan drives, centrifugal pumps, blower and compressor drives, load absorption, and motor starting applications. Further information is contained in bulletin *1457544*, which is available from the Allis-Chalmers Manufacturing Company at 931 South 70th Street, Milwaukee, Wis., upon written request.

TRADE LITERATURE

Power and Control Cable Catalog. The Rome Cable Corporation, Rome, N. Y., has just published a new 60-page catalog describing the company's power and control cable constructions. In a special product section, dimensional data, as well as electrical and physical characteristics are presented covering low- and high-voltage cables, service cables, lighting cables, and station control and municipal signal cables. Copies are available upon request from the Advertising Department, Rome Cable Corporation, Rome, N. Y.

Oil Mist. Alemite Oil Mist, a system of constant and automatic delivery of lubricating oil to all types of machine bearings in air-borne microscopic particles through tubing, has been announced recently by the Alemite Division of the Stewart-Warner Corporation, 1826 Diversey Parkway, Chicago 14, Ill. This system is described in a series of data sheets containing engineering information, a paper presented to the American Society of Lubrication Engineers (booklet), by means of a diagram and models of the system, and case records of machine tests. This data

(*Continued on page 58A*)



Bethlehem's A and B coatings. Note the extra heaviness of the B, which means years of extra service. Each coating has its uses, but even where A will do the job, B is often preferable.

The Strand Coating that Lasts TWICE AS LONG!

If you've been using Bethlehem strand with the A-weight coating (or another brand with extra-galvanized), here's good news. Good because it can save you lots of money.

The Bethlehem A is a mighty fine coating; but there are, of course, many locations where economy dictates a heavier jacket.

For instance, the Bethlehem B-weight. It's *twice* as thick as the A; will normally last twice as long — yet the extra first cost is *very small*.

Even in locations where the A is generally satisfactory, the heavier B-weight is often the logical choice. For, lasting twice as long, it naturally means less frequent strand replacement. And let us repeat: the slight extra cost of the B is as nothing, compared to its extra life.

Nowadays engineers want a strand that will last as long as pole structures treated by modern methods. That's why Bethlehem's heavier coatings are so often called for by farsighted utility companies. When you specify bethanized strand with the pure, electrolytic zinc jacket, you aren't limited to one coating weight — or even two. In addition to A and B, there's a still heavier grade, C, for extremely corrosive conditions. Thus strand life can be matched to the life expectancy of the line itself — with resultant economies.

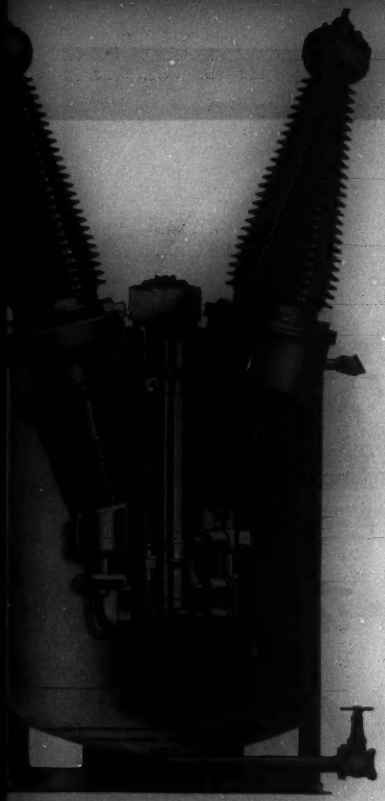
We'd like to give you the full story. Why not ask our representative to spend some time with you and explain more fully?

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

. . . . for Improved High-Voltage Switching



Above:
Sectional Elevation
196/230-kv Rating.

PACIFIC ELECTRIC TYPE RHE OIL CIRCUIT BREAKERS *for*

REDUCED MAINTENANCE
IMPROVED RELIABILITY

Verify the worth of each of these listed features in the light of your own experience

Only One Moving Element in the Tank

Moving as one piece, the rotary blade-structure provides six equal-length gaps in series per pole, totaling 80 to 96 inches, according to rating.

All gaps open at equal speed throughout entire stroke, and open fully before reclosing starts.

The rotary form permits adequate blade acceleration without need of auxiliary levers or multiplying linkage in the contact housings for increasing initial speed.

Nested Sliding-Shoe Contacts

No sensitive adjustments required to fix closed position.

Arcing does not affect surface carrying load current.

Wiping action smooths and cleans surfaces.

Leaf springs apply adequate pressure regardless of wear of the shoes; eliminates need of pressure adjustment.

As moving contacts do not charge auxiliary springs nor drive contact linkage, impact on bushings and battering of stationary contact shoes is negligible.

At left:
OPEN.

At right:
CLOSED.

-Shoe Nested Con-
with Interrupters Re-
).

pters and Blades
ide only).

Improved Interrupters

Oil blast interrupters confine thermal effects within the interrupting chambers. Oil is not directed into or alongside of arc path; however, relatively cool oil vapor rapidly replaces ionized portions. The usual large gas bubble does not form, with the result that ground shock and jar caused by oil displacement within the tank is eliminated.

Oil-gas separators are thereby rendered unnecessary, so are not used.

PACIFIC ELECTRIC
5815 THIRD ST., SAN FRANCISCO 24, CALIF.

PACIFIC "RHE" Oil Circuit Breakers

3-Cycle Interrupting; 10-Cycle Closing;
15- to 45-Cycle Adjustable Reclosing
115, 138, 161, 196/230, and 230 Kv
Continuous Rating, 800 and 1200 Amp
Interrupting Rating to 10,000,000 Kva at 230 Kv

Many of America's leading power systems have installed these circuit breakers, or have them on order.

Oil-Hydraulic Compressed Operating Springs

The compressed operating springs stand ready for action—for years, if necessary—without anything meanwhile having to move or operate.

Operating-spring compression is by motor-operated oil-hydraulic jack which is under pressure only during compression of the springs.

Design interrupting tests up to 9,620,000 kva were conducted on prototype circuit breakers at the Grand Coulee Switchyard in June, 1948.

Motor-Operated Main Mechanism

The opening and closing latches, the closing-energy system, oil-hydraulic decelerators, control circuits, and auxiliary switches are housed in dust-proof cabinet mounted on No. 1 pole. All operating forces are self-contained within compression tubes that surround pull rod and connect main and tank-top mechanism housings.

The velocity of any mechanism part (aside from the opening latch) does not exceed 8 ft. per sec. (the speed of a body falling one foot). Impact is thereby eliminated as a problem.

The mechanism is electrically and mechanically trip-free.

Main Operating Mechanism with doors open. Shows oil-hydraulic cylinder centered between double closing-spring barrels.

Opening Forces Externally at Tank Tops

Each pole has individual external kick-off springs that apply opening force directly to the crank arm of the rotating unit. For ease of inspection, all opening toggle linkage is also outside of the tank. A follow spring at end of pull rod on No. 3 pole completes the opening stroke that was started by the tank-top kick-off springs.

Below: Two 196/230-kv Type RHE's on the line.

Emergency Manual Operation

Should control power fail, manual latch tripping provides a close-open or open-close-open sequence as necessary. If power remains off, two minutes operation of hand oil pump restores full operating energy.

Advanced Design

Integral assemblies and multiple functioning of parts greatly simplify and reduce number of parts and adjustment points. Mechanical linkage interlocking eliminates need for an anti-pumping relay, and it permits reduction of the number of position-check switches to only one.

MFG. CORPORATION
P. O. BOX 419, GARY, INDIANA

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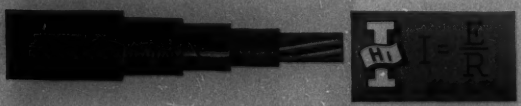
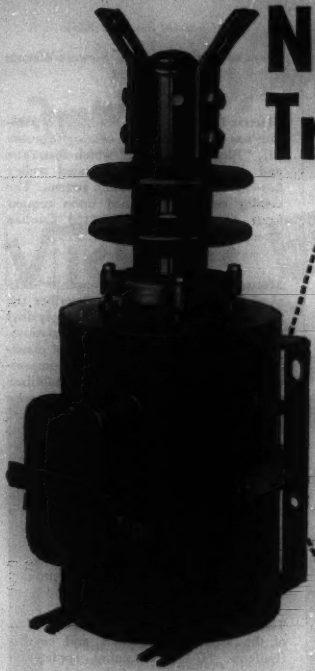
PITTSBURGH ST. LOUIS LOS ANGELES OAKLAND, CAL.



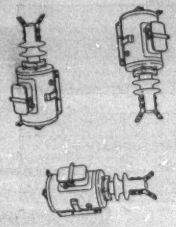
ROCKBESTOS A.V.C.
has a HIGHER AMPERE RATING

New Outdoor Current Transformer Type KO



Type KO Outdoor (compound-filled) current transformer. Available in standard current ratings up to and including 800 amperes and three voltage classes: 5, 8.7 and 15 KV.

Mounts in Any Position



Type KO current transformers solve your installation problems in more ways than one. Mount on frame, pole or platform, in any position to meet your system requirements.

ALLIS-CHALMERS
CURRENT TRANSFORMERS

Highly Accurate on Metering Burdens

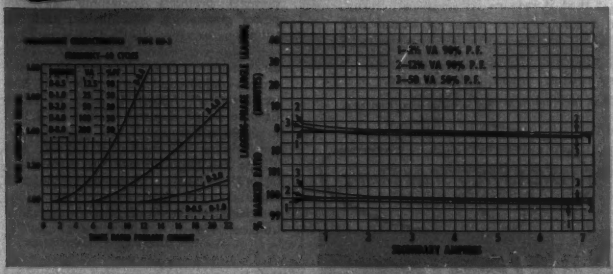
NEW VERSATILITY in mounting . . . high accuracy in metering and heavy duty relay application — that's the story on the new Type KO out-door current transformer. Linemen like it because they can install it quickly, easily in any position.

Primary leads are brought out conveniently to blade type terminals through a porcelain bushing designed with generous creep surface. Secondary leads terminate in a weather-proof terminal box. Box cover readily swings open after loosening the barrel type locking bolt — no parts to drop or lose. Secondary connection through conduit openings made to stud type terminals in this sealable compartment.

Type KO transformer housing is completely welded, pressure tested and hermetically sealed. Maximum insulation strength is achieved by compound filling under a "vacuum-pressure" process which entirely eliminates air. This results in low power factor and a maintenance-free installation.

For more information on Allis-Chalmers wide range of instrument transformers write for bulletin 61B7168 or see your nearby A-C sales representative. A-3143

ALLIS-CHALMERS, 931A SO. 70 ST. MILWAUKEE, WIS.



The excellent performance of Type KO current transformers is represented in the above curves. They meet or better ASA and NEMA standards.

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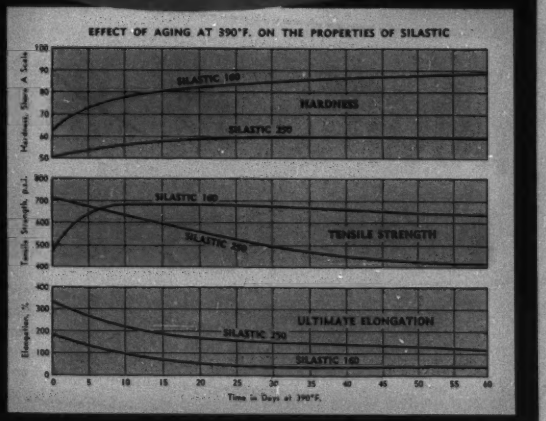
Pioneers in Power and Electrical Equipment from Generation through Utilization

Long after organic rubber melts or becomes brittle...

SILASTIC* still stays Elastic!



We're talking about an elastomer that retains its rubbery properties at temperatures far above and far below the limits of any other elastic material. That is indicated by the effects of accelerated aging at 350°F. on the properties of two typical Silastic stocks with brittle points in the range of —70° to —130°F.

Silastic is being widely used at temperatures in the range of 250° to 600°F. and at temperatures ranging from —75° to below —100°F. It shouldn't be called a rubber because that term invites comparisons that are not valid. At room temperatures, the physical properties and abrasion resistance of Silastic are well below the values normally associated with rubber. Conversely, at temperatures well within the serviceable limits of Silastic, rubber rapidly becomes a soft gum or a brittle solid.

The important thing about Silastic is that it retains its physical, chemical and dielectric properties over a temperature span of about 600 Fahrenheit degrees. When you need rubbery properties or good dielectric properties in a resilient and flexible material at temperatures beyond the limits of ordinary rubber, investigate Silastic.

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(*Continued from page 52A*)

may be obtained from Stewart-Warner Corporation upon request.

Electric Feedrail. The Feedrail Corporation has issued a 64-page catalog (number 25), "Electric Feedrail," which illustrates and describes their prefabricated trolley busway electrical distribution system. The catalog may be obtained upon request from the Corporation at 125 Barclay Street, New York 7, N. Y.

Monsanto Plasticizers. Monsanto technical bulletin number *O-70* describes the properties and uses of typical polyvinyl chloride film and sheeting formulations. Information on the various types of plasticizers and their functions and the composition and relative values of seven stabilizer systems also is included. Copies may be obtained from the Monsanto Chemical Company, Organic Chemicals Division, 1700 South Second, St. Louis 4, Mo.

Vibrotest Data. New data on 29 Vibrotest insulation resistance testers has been released by Associated Research, Inc., 3754 Belmont Avenue, Chicago 18, Ill. The booklet, Vibrotest bulletin *24*, is available upon request from the company.

Thermocouple Manual. A new edition of the Wheelco data book and catalog (bulletin *TC-8*), containing application recommendations and information concerning instrument sensing units and associated accessories, has been released by the Wheelco Instruments Company, 847 West Harrison Street, Chicago 7, Ill. The manual is available upon request.

Allis-Chalmers Bulletins. The Allis-Chalmers Manufacturing Company has issued five new bulletins: "Electrifugal Pump," *52B6140B*, contains design and construction features of a close-coupled pump and motor—the Electrifugal; "Allis-Chalmers Power Equipment," *25B6150C*, presents products commonly used on power generating, transmission, and distribution systems; "Allis-Chalmers Synchronous Condensers," *05B7285*, covers air-cooled, outdoor air-cooled, and hydrogen-cooled condensers; "Type H Motor Starters," *14B6410A*, describes Allis-Chalmers type H motor starters for 2,300- to 5,000-volt squirrel-cage, wound-rotor, synchronous and multispeed motors; and "Type 256 High-Voltage Air Break Contactor," *14B7303*. These Allis-Chalmers bulletins are available upon request to the company at 931 South 70th Street, Milwaukee, Wis.

Bakelite Polyethylene. The Bakelite Division of the Union Carbide and Carbon Corporation, 300 Madison Avenue, New York 17, N. Y., has issued a new booklet, "Bakelite Polyethylene," which summarizes the characteristics, development, and latest applications of this thermoplastic material. The booklet is available upon request.

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HIGH POWER

For 60 cps power sources—27 styles—maximum output powers from 62 watts to 4200 watts.

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For 60 cps power sources—28 styles — maximum output powers from milli-watts to 108 watts. For 400 cps power sources —20 styles—maximum output powers from 30 watts to 385 watts.

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For 60 cps power sources—22 styles — maximum output powers from ½ watt to 1200 watts.

All amplifiers furnished complete with Vickers special Selenium Rectifiers.

Now More Than 90 STANDARD Styles Offer These Advantages

- HIGH PERFORMANCE
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Servomechanisms — Line-To-Line Voltage Regulators — Hydraulic Transmission Controls—A-C and D-C Generator Voltage Regulators—Speed and Frequency Regulators — Lamp and Furnace Controls—Temperature Regulators—Time Delay Devices.

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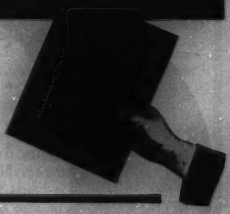
for information on the *complete* line of Vickers Standard Magnetic Amplifiers. Please make request on your letterhead.



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GROUND RESISTANCE TESTING
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YOU can be sure of safe, effective grounding of all types of electrical systems when you test with the light, easy-to-use Vibroground. Simple operation and built-in accuracy virtually eliminate reading errors. No leveling, cranking or outside power source is necessary; and direct readings are independent of auxiliary probe resistance.

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BIBLIOGRAPHY on ELECTRONIC POWER CONVERTERS

A compilation of considerable reference data on power rectifiers and inverters, published in chronological sequence beginning with 1903. Items are arranged alphabetically by the author's surname, and are further classified according to text matter. Prepared by the Subcommittee on Papers and Speakers of the AIEE Electronic Power Converter Committee.

Priced at $1.00 ($0.50 to AIEE members), S-35 (February 1950) is available from the Order Department, AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, 33 West 29th Street, New York 18, N. Y. 12-50

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ELECTRICAL ESTIMATOR—ENGINEER. Qualified to assume full responsibility, Estimating, Engineering, Construction Administration, Sales. Now employed as General Manager volume approximately million dollars annually. Desire to locate New York, New Jersey, Pennsylvania, Maryland. Salary open. Available about December 15. Address: Box 994, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

PROJECT ENGINEER, Instrument specialist, over seven years experience on design and production of aircraft instruments, relays, alarm systems, etc. Developed ruggedized panel type A.C. voltmeters and D'Arsonval electrical instruments, capable of heading project or development group. Résumé available. Address: Box 1008, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

MANUFACTURING ELECTRICAL ENGINEER, age 35, B.S. in E.E. Registered professional electrical engineer; Journeyman machinist and toolmaker; 11 yrs. diversified experience in manufacturing with positions as materials and development engineer, time and motion study, methods and tooling, production, foreman and general foreman of electric motor manufacturing, and tool supervisor. Experience with union negotiations. Past 3½ years employed as electrical instructor. Desires position as supervisor requiring above-average intelligence, initiative, and performance, connected with manufacturing. Best reference; location immaterial. Address: Box 1009, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

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ELECTRICAL ENGINEER, age 36. Have degree and professional license. Chief Engineer large industry 2 years. Professor of E.E., State University, 3 yrs. Design, distribution, transmission and industrial distribution, all phases; also 2 yrs. industrial electronics. Locate anywhere, $10,000 per year. Write for complete specifications; Box 1019, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

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DEVELOPMENT ENGINEER—ELECTRONICS—Recent graduate in Electrical Engineering of Physics with interest and aptitude for development of electrical controls for special purpose production machinery. Prefer man with one or two years' experience along these lines. Excellent working conditions. Permanent. Please send complete résumé to Box 1013, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

PATENT ENGINEERS—Large and well established Ohio corporation in the automotive field has openings for patent engineers to act in a liaison capacity between Engineering and Patent Departments. The work comprises fact-finding investigations, preparation of preliminary drafts of patent applications and general assistance to technical personnel in the fields of mechanical and electrical engineering. In answering, give details of education, experience and salary expected, including a photograph. All inquiries and applications are strictly confidential. Address: Box 1014, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

ELECTRICAL ENGINEER—recent graduate, preferred age 25–30, for general engineering work in electrical and instrument departments of chemical manufacturing company. Location, Western New York State. Address: Box 1015, ELECTRICAL ENGINEERING, 500 Fifth Avenue, New York 18, N. Y.

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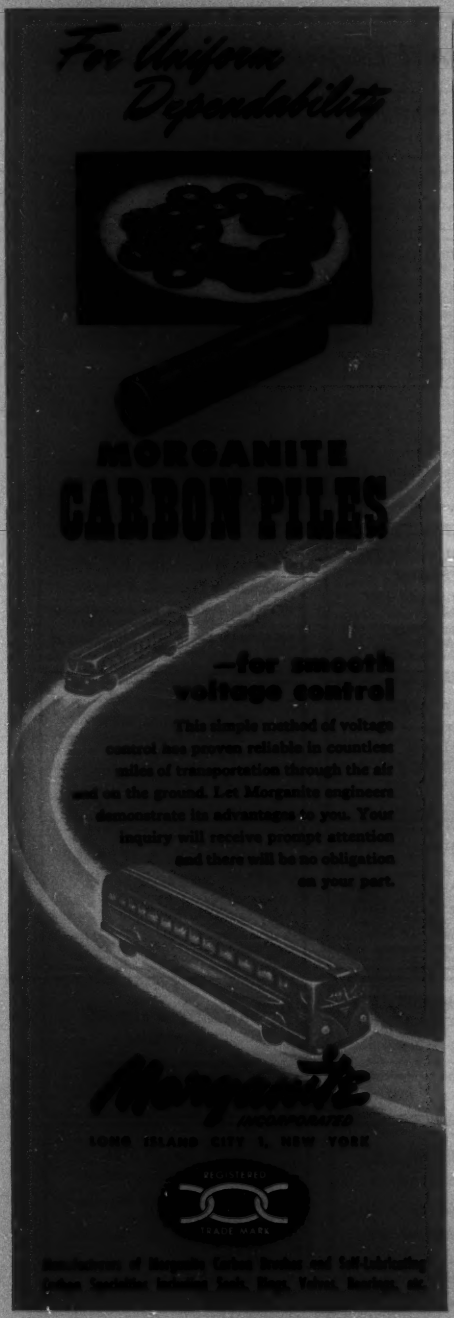
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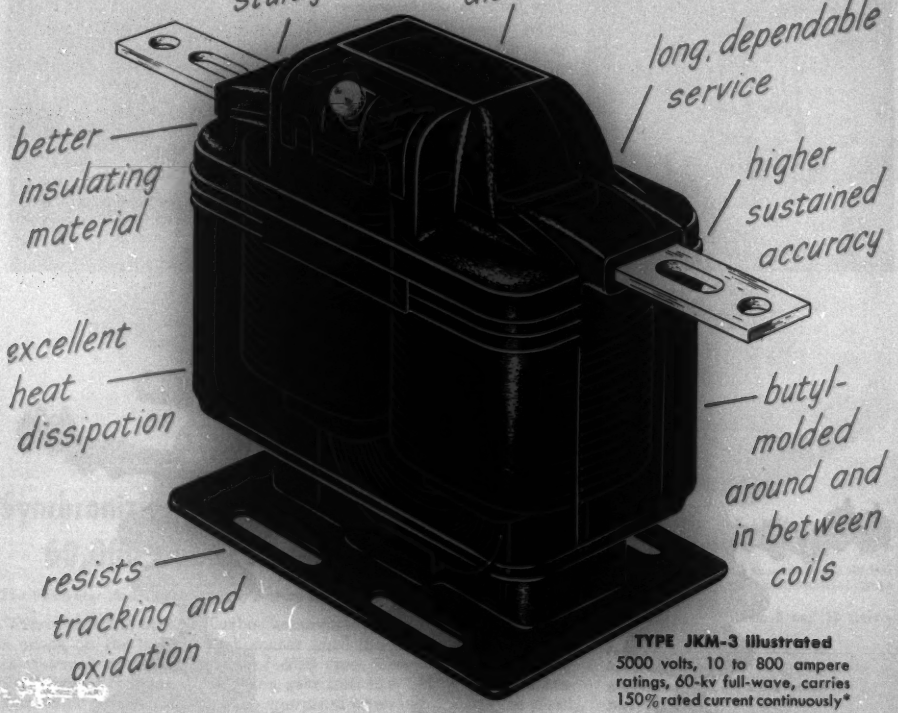

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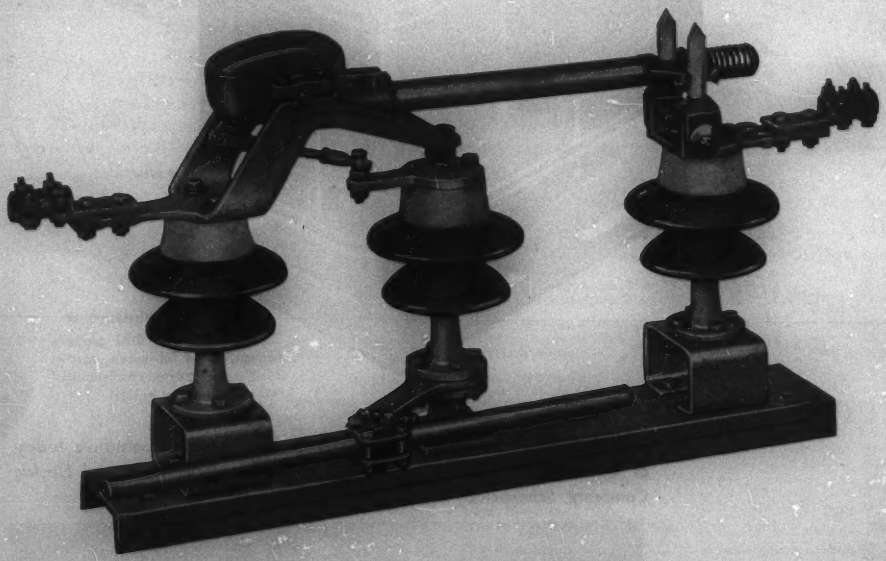

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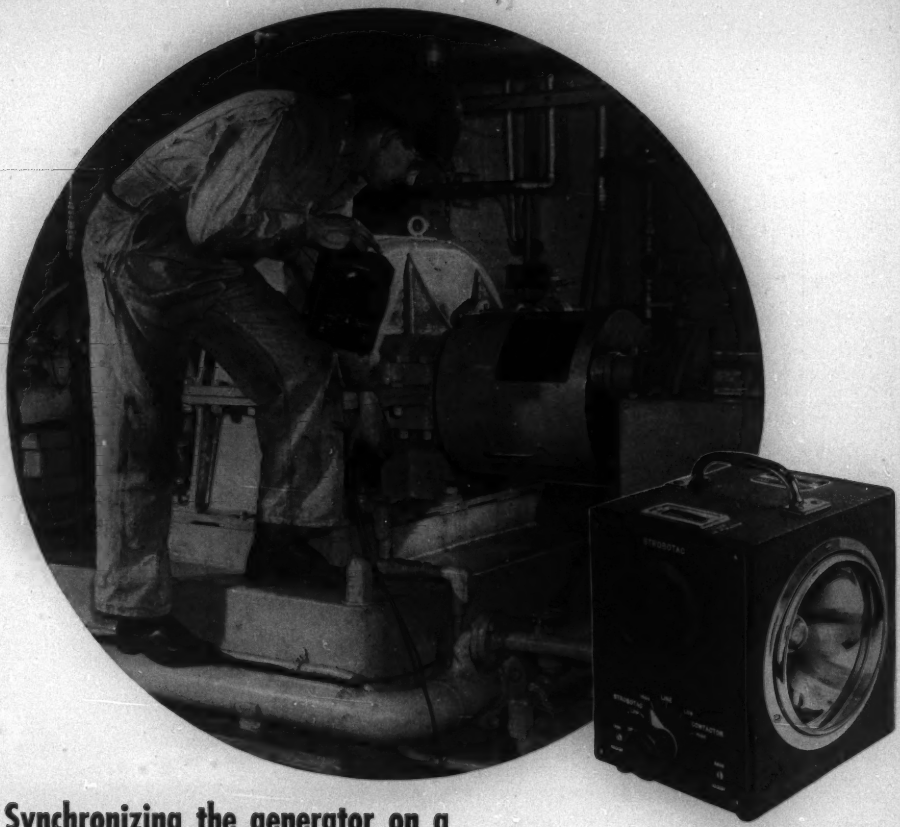

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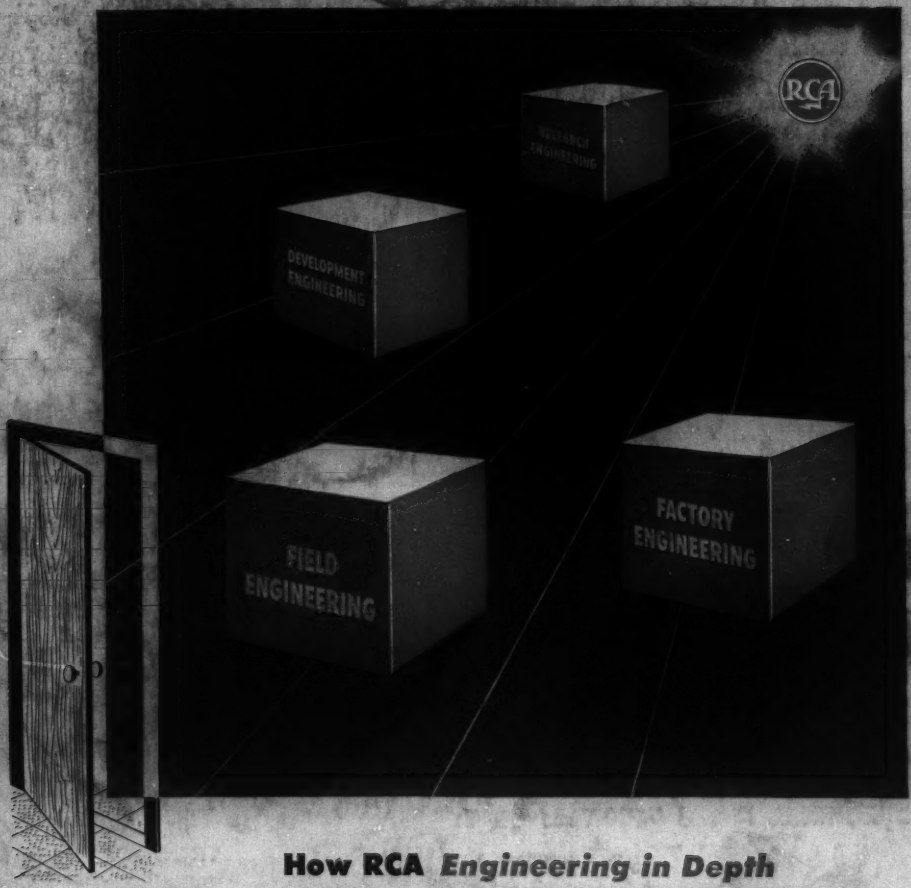

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